

The Development and Evaluation of an Approach to  
Auditory Display Design Based on Soundtrack  
Composition

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### **Statement of Originality**

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## **Abstract**

This thesis presents the development and evaluation of a new approach (SoundTrAD) to designing auditory interfaces. The proposed approach combines practices and concepts from film soundtrack composition with established approaches to general user interface design. The synthesis of the two design approaches from different areas of design into a novel approach may be viewed as an example of conceptual integration, (also known as conceptual blending). The process of developing and evaluating SoundTrAD broadly follows a methodology of Research through Design.

The thesis presents four user studies as part of an iterative design and evaluation process. Each study involves a mixture of expert and novice end-users which provides new information and identifies new questions and design issues for the subsequent studies.

The first study explores how an idea from film composition (the cue sheet) can be used in auditory interface design to help designers place and organise sound elements, and to better understand auditory design spaces. In order to make this concept work in the new context, it is combined with the scenario concept from general interaction design to provide designers with reference linear sequences of events and actions.

The second study used thematic analysis to investigate how information to be sonified can be characterised and analysed for features that can be mapped in to sound. The study also explores the development of a timeline on which the sound design ideas from soundtrack composition for individual events, can be placed and in principle moved in order to cater for multiple use-case scenarios.

The third study presents an iteration of this, including further development of both the task analysis and mapping technique. The study also explores the idea in principle of an interactive timeline that can be manipulated by the designer in order to re-arrange and audition sound events.

The final study brings the studies together by obtaining feedback on the success of a final version of SoundTrAD.

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# Contents

<b>1</b>	<b>Introduction</b>	<b>12</b>
1.1	Motivation . . . . .	15
1.2	Research Questions and Supporting Objectives . . . . .	17
1.3	Thesis Outline . . . . .	18
1.4	Associated Publications and Presentations . . . . .	19
<b>2</b>	<b>Literature Review</b>	<b>20</b>
2.1	Soundtrack Composition . . . . .	20
2.1.1	Why Film Sound? . . . . .	20
2.1.2	Functions of Sound in Film . . . . .	21
2.1.3	Types of Film Sound . . . . .	21
2.1.4	The Three Listening Modes . . . . .	23
2.1.5	Techniques and Technology to Create Soundtracks . . . . .	23
2.1.6	Interaction and Novel Approaches for Film Composition . . . . .	25
2.2	Auditory Displays . . . . .	26
2.2.1	Overview and Definitions . . . . .	26
2.2.2	History of Auditory Display Development . . . . .	30
2.2.3	Techniques for Employing Sound in the User Interface . . . . .	34
2.2.4	Software Tools for the Sonification of Data . . . . .	39
2.2.5	Perspectives on Auditory Display Design . . . . .	47
2.2.6	Methods for Auditory Display Design . . . . .	54
2.2.7	Approaches to Auditory Display Design that draw on Sound-track Composition . . . . .	56

<b>3</b>	<b>Approach and Research Methods</b>	<b>61</b>
3.1	More on Conceptual Blending . . . . .	62
3.2	A Review of Creating Interfaces . . . . .	63
3.2.1	Summary and Example . . . . .	67
3.3	A Review of Creating Soundtracks . . . . .	68
3.4	Bringing the Two Together . . . . .	70
3.4.1	Similarities . . . . .	71
3.4.2	Differences and Incompatibilities . . . . .	73
3.5	The Aim of SoundTrAD: What Can It Support? . . . . .	74
3.6	Research and Evaluation Methods . . . . .	75
3.6.1	Research Through Design . . . . .	75
3.6.2	Mixed Methods . . . . .	76
3.6.3	The Thesis Outline and Development of SoundTrAD . . . . .	79
<b>4</b>	<b>Study One: Scenarios And The Cue Sheet</b>	<b>82</b>
4.1	Requirements Gathering . . . . .	84
4.1.1	Task Analysis . . . . .	87
4.2	Developing SoundTrAD: Scenarios and the Cue Sheet . . . . .	88
4.3	Evaluating SoundTrAD and the Cue Sheet . . . . .	94
4.4	Findings . . . . .	99
4.4.1	Method Stages . . . . .	103
4.4.2	A Summary of the Findings . . . . .	105
4.4.3	Limitations . . . . .	107
4.4.4	Conclusion . . . . .	108
<b>5</b>	<b>Development of SoundTrAD</b>	<b>109</b>
5.1	Summary of the Aims and Subsequent Developments to SoundTrAD	112
5.2	Number 1: Requirements Gathering . . . . .	114
5.2.1	The Supporting Method Steps for SoundTrAD . . . . .	116
5.3	Number 2: Conceptual Design Stage . . . . .	118
5.4	Number 3: Detailed Design Stage . . . . .	119
5.4.1	Toward a Database of Sound ideas . . . . .	124
5.5	Summary of SoundTrAD Development . . . . .	127

<b>6</b>	<b>Study Two: Evaluating SoundTrAD</b>	<b>130</b>
6.1	Cue Sheet and Timeline Development . . . . .	131
6.2	Data Collection and Evaluation . . . . .	135
6.3	The Study . . . . .	141
6.4	Findings . . . . .	144
6.4.1	Limitations . . . . .	158
6.4.2	Summary . . . . .	159
<b>7</b>	<b>Study Three</b>	<b>163</b>
7.1	Developments to SoundTrAD . . . . .	165
7.1.1	Terminology: The Events . . . . .	165
7.1.2	Requirements Gathering . . . . .	169
7.1.3	The Sounds and Mappings . . . . .	173
7.2	Tool Development . . . . .	175
7.2.1	The Cue sheet . . . . .	176
7.2.2	The Database . . . . .	177
7.2.3	The Timeline . . . . .	180
7.3	Evaluation . . . . .	181
7.3.1	Tasks . . . . .	181
7.3.2	Data Gathering . . . . .	184
7.4	Findings and Analyses . . . . .	186
7.4.1	Participant Designs . . . . .	206
7.4.2	Summary and Discussion . . . . .	209
7.4.3	Design Implications and Future Work . . . . .	213
<b>8</b>	<b>Study Four</b>	<b>214</b>
8.1	Addressing Further Questions . . . . .	216
8.2	Developments to SoundTrAD . . . . .	219
8.2.1	Requirements and Data Gathering . . . . .	220
8.2.2	Mappings . . . . .	224
8.2.3	Event Layout and the Timeline . . . . .	226
8.2.4	Other Features: Mixing the Audio . . . . .	228
8.3	The Evaluation . . . . .	229

8.3.1	Findings . . . . .	231
8.3.2	Summary of The Findings . . . . .	242
<b>9</b>	<b>Discussion and Conclusions</b>	<b>244</b>
9.1	Approaches, The Studies and The Findings . . . . .	246
9.1.1	The Studies . . . . .	248
9.1.2	A Reflection on The Methods Used . . . . .	252
9.2	Contributions . . . . .	255
9.2.1	More on The Current Prototype and Computer-Based Tool .	256
9.2.2	Limitations . . . . .	259
9.3	Future Work . . . . .	259
<b>A</b>	<b>Cue Sheets from Study 1</b>	<b>261</b>
A.1	Example for Study . . . . .	261
A.2	Cue Sheet From Participant 3. . . . .	261
A.3	Sound Design Choices . . . . .	262
<b>B</b>	<b>System Usability Scale</b>	<b>265</b>
<b>C</b>	<b>Surveys and Transcriptions Study Two</b>	<b>266</b>
C.1	Transcriptions and Thematic Analysis Phases 1-4 . . . . .	266
<b>D</b>	<b>Study Three Tasks and Open-Ended Feedback</b>	<b>295</b>
D.1	Task 1 . . . . .	295
D.2	Section 2. Open-Ended Responses . . . . .	303
<b>E</b>	<b>Study Four Tasks, Questions and Open-Ended Feedback</b>	<b>310</b>
E.1	Tasks . . . . .	310
E.2	Open-Ended Responses . . . . .	318
	<b>References</b>	<b>324</b>

# List of Figures

2.1	Thomas Hermann’s model of sonification and auditory display. . . .	29
3.1	Turner’s visualisation of conceptual blending. . . . .	63
3.2	Relationship between tasks, actions, triggers and status. . . . .	66
3.3	A blended Space: stages and steps for SoundTrAD. . . . .	71
4.1	Cue sheet used during pilot study one. NB. There is a misspelled word in column 3; ‘their’ instead of ‘there’. This was an error that was present during the study. . . . .	92
4.2	Example of a filled out cue sheet using the Artist scenario. . . . .	94
4.3	Scenario 1 for pilot study 1 . . . . .	97
4.4	Scenario 2 for pilot study 1 . . . . .	97
5.1	The method steps for analysing requirements for both the user of the auditory display and the information that needs to be represented through sound. . . . .	118
5.2	The timeline. . . . .	119
5.3	Database representing characters. . . . .	125
5.4	Database representing actions and behaviours. . . . .	125
5.5	Database representing objects, properties and behaviours . . . . .	126
5.6	Database representing locations/environments. . . . .	127
5.7	Database representing transition points. . . . .	128
5.8	Database representing emotions and moods. . . . .	129
6.1	Cue sheet at this stage of the development of SoundTrAD. . . . .	133
6.2	Timeline (blank) at this stage of the development of SoundTrAD. . .	133
6.3	Event layout. . . . .	142

6.4	Phase 4. Thematic map 1. . . . .	146
6.5	Phase 6. Final themes. . . . .	155
6.6	SUS usability of the system. . . . .	158
7.1	Dix's event status representation. . . . .	166
7.2	Event relationships. . . . .	170
7.3	Cue sheet (blank). . . . .	177
7.4	Cue sheet with example. . . . .	177
7.5	Layout of database. . . . .	179
7.6	Timeline used for study three. . . . .	181
7.7	Cue sheet-timeline relationship. . . . .	183
7.8	Q1a. Usefulness of the method for designing audio for the interface. . . . .	187
7.9	Q1b: Requirements and cue sheet. . . . .	187
7.10	Q1c. Mappings and database. . . . .	189
7.11	Q2a. Benefit from moving events and playing them back. . . . .	192
7.12	Q3a: Understand the different types of events. . . . .	194
7.13	Q6a. Confidence felt using the method. . . . .	200
7.14	Q8. SUS usability of the method. . . . .	203
7.15	Q9a. Usability of the tools and interfaces. . . . .	204
7.16	Example of participant completed cue sheet and timeline. . . . .	209
8.1	The Cue Sheet. . . . .	223
8.2	Entering the dataset. . . . .	224
8.3	Entering a dataset to map to pitch/melody. . . . .	226
8.4	Background sounds. . . . .	227
8.5	Foley and motifs. . . . .	227
8.6	Timeline. . . . .	228
8.7	Change the playback levels of the events on the timeline. . . . .	229
8.8	Q1. Usability rating. . . . .	233
8.9	Q2. SUS Ratings. . . . .	235
8.10	Q3. Enjoyability. . . . .	235
8.11	Q4. Usefulness. . . . .	237
A.1	Example scenario. Study 1. . . . .	261

A.2	Example Of A Completed Cue Sheet. Study 1. . . . .	262
A.3	Participant 3, scenario 1. . . . .	264
A.4	Scenario 1 . . . . .	264
C.1	Thematic analysis. Participant 1. . . . .	267
C.2	Thematic analysis. Participant 2. . . . .	268
C.3	Thematic analysis. Participant 3, part 1. . . . .	269
C.4	Thematic analysis. Participant 3, part 2. . . . .	270
C.5	Thematic analysis. Participant 4, Part 1 . . . . .	271
C.6	Thematic analysis. Participant 4, part 2. . . . .	272
C.7	Thematic analysis. Participant 5, part 1. . . . .	273
C.8	Thematic Analysis. Participant 5, part 2. . . . .	274
C.9	Thematic analysis. Participant 6, part 1. . . . .	275
C.10	Thematic analysis. Participant 6, part 2. . . . .	276
C.11	Thematic analysis. Participant 6, part 3. . . . .	277
C.12	Thematic analysis. Participant 6, part 4. . . . .	278
C.13	Thematic analysis. Participant 6, part 5. . . . .	279
C.14	Thematic analysis. Participant 6, Part 6. . . . .	280
C.15	Thematic analysis. Participant 6, part 7. . . . .	281
C.16	Thematic analysis. Participant 6, part 8. . . . .	282
C.17	Thematic analysis. Participant 7, part 1. . . . .	283
C.18	Thematic analysis. Participant 7, part 2. . . . .	284
C.19	Thematic analysis. Participant 7, part 3. . . . .	285
C.20	Thematic analysis. Participant 7, part 4. . . . .	286
C.21	Thematic analysis. Participant 7, part 5. . . . .	287
C.22	Thematic analysis. Participant 8, part 1. . . . .	288
C.23	Thematic analysis. Participant 8, part 2. . . . .	289
C.24	Thematic analysis. Participant 8, part 3. . . . .	290
C.25	Thematic analysis. Participant 8, part 4. . . . .	291
C.26	Thematic analysis. Participant 8, part 5. . . . .	292
C.27	Thematic analysis. Participant 8, part 6. . . . .	292
C.28	Thematic analysis. Participant 9, part 1. . . . .	293
C.29	Thematic analysis. Participant 9, part 2. . . . .	294

E.1	Introduction and scenario. . . . .	311
E.2	Data and events. Task one. . . . .	311
E.3	Data and events. Task two. . . . .	313
E.4	Layout it out. Task three. . . . .	314
E.5	Pitch and speed. Task four. . . . .	315
E.6	Background. Task five. . . . .	316
E.7	SFX/Foley. Task six. . . . .	317
E.8	Arranging audio. Task seven. . . . .	318



# List of Tables

3.1	Parallels between audio interface design and soundtrack composition.	70
4.1	Identified auditory display events for scenarios 1 and 2. . . . .	100
6.1	Mappings of events/information on the cue sheet to sound suggestions on the timeline. . . . .	161
6.2	Experience of AD and interaction design and music composition. . .	162
7.1	Levels of experience. . . . .	186
7.2	Q4. How many scenarios? . . . . .	196
7.3	Q5a. Add ideas to the database. . . . .	197
7.4	Q7a. Like to use method again? . . . . .	202
7.5	Identified events and their layout. . . . .	207
7.6	Completed cue sheets participants 1-6. . . . .	210
7.7	Completed cue sheets participants 7-12. . . . .	211
8.1	Completed cue sheets participants 1-6, with highlighted text to mark event identification. . . . .	221
8.2	Completed cue sheets participants 7-12, with highlighted text to mark event identification. . . . .	222
8.3	Experience of interaction design and music composition. . . . .	230
8.4	Understanding of auditory display and sonification pre and post study.	231
9.1	Usability (SUS) for Studies 2, 3 and 4 . . . . .	254
9.2	Study Comparisons. What was being evaluated in each study. . . . .	254
A.1	Scenario 1. Participant sound choices and categorisations for the ADs.	263
A.2	Scenario 2. Participant sound choices and categorisations for the ADs.	263

# List of Abbreviations

AD - Auditory Display

AUI - Auditory User Interface

DAW - Digital Audio Workstation

FQ - Further Question

GUI - Graphical User Interface

HCI - Human-Computer Interaction

IR - Implementation Recommendation

OE - Open Ended

P - Participant

PMSon - Parameter Mapping Sonification

RtD - Research Through Design

Stats - Statistics

TA - Thematic Analysis

UI - User interface

# Chapter 1

## Introduction

*‘Perhaps sonification will play the role of enhancing the appreciation and understanding of the data in a way that is so subtle and intuitive that its very existence will not be specifically appreciated yet it will be clearly missed if absent (rather like the best film music, which enhances the emotion and depth of characterization in a movie without being noticed)’*

(Hermann, Hunt, & Neuhoff, 2011a, p.6)

Using sound to communicate meaning is central to its use in the soundtrack of a film. The sounds within a soundtrack can be used to extend the boundaries of the narrative beyond the screen and communicate intentions, future and past events, the status of an object, the types and the character of actions, moods, inner feelings and the thoughts of a character as well as time and place (Beauchamp, 2005).

When going to ‘see’ a film, the cinematic visual display is important but so too is the soundtrack, which is often seen as less important and a ‘minor player’ in relation to the visual (Somers, 2000; Leplâtre & McGregor, 2004). Film music scholar Kalinak (1991) argued that because the music was traditionally added in the post-production stage, it has not been considered an equal partner to the other components of a film’s signifying system. The addition of audio is taken for granted, often goes unnoticed or ‘unheard’ (Gorbman, 1987) and comes second to the visual, but imagine viewing your favourite film with the sound turned down.

The view that audio is considered second to the visual is a common held view about the use of audio within the human-computer interface (Bishop & Sonnenschein, 2012) and it is arguable that this contributes to the lack of appreciation

as to why and how it can be used. However, there are reasons why audio in the interface is needed and is, in some cases, essential.

It can be argued that the use of audio in the interface is worth considering as technologies get smaller, portable and ubiquitous. Shrinking screen sizes can limit the amount of visual information that can be displayed and easily understood. Audio provides a possible means to address this problem as it provides an alternative means of information presentation. Similarly, sound is also a useful medium of communication when eyes are busy and full visual attention cannot be given to the screen. Additionally, sound can be useful when multi-tasking and both visual and audio channels of communication are needed. Finally, sound is often essential to users with visual impairments, for whom in many cases, sound is one of a restricted number or the only channel of information. However, despite these clear reasons to support sound in the interface, sound is considered to be under-utilised in this context (Brewster, 1991; Alty, 1995; Frauenberger & Stockman, 2009).

### **Example: The Artist Scenario**

Documented next is a scenario that provides an example of where auditory representation of information in the interface could be beneficial.

*Imagine an artist who is working in her studio. She wants to monitor hits on her website whilst painting. She is busy with the task of painting and cannot rely on visually monitoring the website. She would like to rely on sound to be made aware of live hits to her website. Specifically, she would like to know how many people are viewing it at any one time and how long they stay (so when they leave). She cannot watch a visual monitor of this and would also like to leave the live monitoring on whilst working and/or have it updates when she interacts with the monitoring system.*

Designing audio for this scenario raises questions around the sounds that should be used to represent the events to be monitored. Specifically, some of the issues that need to be taken into account when designing the sounds for this auditory display

are: 1) Easy association of the sounds with the events they represent, which in turn may need to take into account the background and experience of the user. 2) The need for the sounds to be appropriate to the context (the space, the activities, other people) in which the display is being used.

It is these kind of problems, or these kinds of issues that provide the focus for the research described in this thesis, drawing for inspiration on what has been learned from the relatively well-established practice of soundtrack composition.

Many approaches to creating auditory interfaces exist, ranging from those that focus on the conceptual stages of identifying the design problem, a review of which can be found in the research of Brazil (2009), to those that focus more on specific mapping techniques of information to sound (Hermann, Hunt, & Neuhoff, 2011b). However, after Frauenberger, Stockman, and Bourguet (2007) carried out a survey and collated approaches to auditory display design, the first and second author still concluded in a later publication that, despite the number of approaches, ‘unsupported design decisions were found on all levels of the design process’ (Frauenberger & Stockman, 2009, p.9). It has been pointed out that there is the lack of methods that enable the designer to move successfully from a conceptual design to a physical prototype of their interface (Brazil & Fernström, 2009) and it is arguable that this could be down to the lack of centralised design knowledge as proposed by Frauenberger and Stockman (2009). As Brazil and Fernström (2009) observed, there is no single method that can deal with the complex socio-cultural context of auditory display design.

It is thought that the methods for creating auditory displays are ad-hoc, scattered across a number of sources and not accessible to novice interface designers (Frauenberger & Stockman, 2009; Brazil, 2009) and that sound design for user interfaces is often based on intuition and available technology, rather than a framework or theoretical analysis (Pirhonen, Murphy, McAllister, & Yu, 2006). It has also been argued that methods that enable a novice designer to build an auditory display creatively are not fully developed and that design knowledge is not disseminated outside of an expert field of knowledge. This is exemplified by the observation from Stephen Barrass and Christopher Frauenberger, that ‘the knowledge of how to build a ‘good’ auditory display is hidden in the experience of the experts and creativity of the

artists’ (Barrass & Frauenberger, 2009, p.1). This highlights the importance of demystifying the process of creating an auditory display for novice designers. There are, after all, potential benefits to considering the role of the novice designer, as it could lead to the importance of sound in user interfaces becoming more widely appreciated.

## 1.1 Motivation

When it comes to the creation and placement of sounds within a soundtrack, there are established techniques and tools to support the principles behind how sound can best be utilised. This is not to say that composing and designing sound for a soundtrack is not a highly artistic, intuitive and personal process; but rather, that this artistic approach is fundamentally guided and supported. Soundtracks are familiar and expected, functional and well-established. This is arguably down to the body of knowledge and practice that has been accrued concerning the development and production of films and their associated soundtracks.

The use of sound in the human-computer interface, however, does not have the same widely established tools and techniques. There are theories about why soundtrack composition should be used in the design of ADs (Bishop & Sonnenschein, 2012), but these theories remain just that and have not generally been instantiated and evaluated in terms of practical solutions. As is the case for soundtrack composition, central to the design of auditory displays must come a consideration of the aesthetics, as Barrass argued, a ‘consideration of aesthetics could transfer this field from a scientific curiosity to a popular mass medium’ (Barrass, 2012, p.177).

This thesis provides a solution to the question ‘what can soundtrack composition bring to the creation of auditory displays?’ and provides a systematic, empirical evaluation of that solution across a range of scenarios and levels of user experience. Specifically, the thesis describes the investigation into whether a method and supporting tools based on ideas from soundtrack composition and interface design could be synthesised to support the structured development of auditory displays.

For the sake of this written thesis, the method and set of supporting tools has been called ‘**SoundTrAD**’ in order to distinguish between the method and supporting tools that were developed and the research methodologies that were used to

achieve this.

## **Wicked Problems**

The development of SoundTrAD can be described as a ‘wicked problem’. Wicked problems were defined by (Zimmerman, Forilizzi, & Evenson, 2007; Zimmerman, Stolterman, & Forilizzi, 2010); when discussing research through design as a methodology, as problems that cannot be reduced to a bounded set of simple issues. The exploration of the two disciplines, soundtrack composition and auditory display design, with the aim of developing SoundTrAD, was and is by its very nature, a complex and messy problem. Both disciplines have their own histories and practices, with experts who espouse particular philosophies which are sometimes in conflict.

Therefore, using traditional research methods that belong to human-computer interaction (HCI) or music, for example, arguably, would not have done the research justice. As a consequence, a research through design (RtD) methodology was adopted in the process of the iterative design and evaluation of SoundTrAD.

More detail is given in chapter 3, section 3.5.1 where specific details of the methods used in this research are discussed. In summary however, RtD has been described as a ‘holistic approach of integrating knowledge and theories from across many disciplines’ and an approach that supports an iterative research process to ‘reframing the problematic situation’ (Zimmerman et al., 2010, p.314). This made RtD a highly suitable approach to underpin this research and the iterative development and evaluation of SoundTrAD.

Furthermore, the overall approach taken to the development of SoundTrAD was inspired and informed by the theory of conceptual blending. In research by (Fauconnier & Turner, 2003a), conceptual blending was viewed as the idea to construct a partial match between two inputs and to ‘selectively project’ from these two inputs into what the authors term a blended mental space. As such, the development of SoundTrAD was inspired by the idea of constructing a partial match, or looking for parallels between the two underlying disciplines of soundtrack composition and interface design. Section 3.3 in chapter 3 demonstrates this and represents a ‘blended space’ where soundtrack composition and AD design come together and, as a result, formed a basis for SoundTrAD.

In summary, It was felt that RtD as a methodology and conceptual blending as an underpinning theory both lent themselves well to the development of SoundTrAD.

## 1.2 Research Questions and Supporting Objectives

Throughout this PhD the primary research aim was to investigate what soundtrack composition can bring to the design of auditory displays, with the specific goal to develop SoundTrAD. Listed below are a set of objectives, each of which provided a step along the way to addressing the overall research aim.

- Literature search and analytical comparison: compare the disciplines of soundtrack composition and interface design. Draw on conceptual blending and identify parallels and differences between the two disciplines. Propose a unique perspective on how to develop SoundTrAD.
- Devise and refine methodology: identify a position and approach and the research methods that will be used to investigate, design and evaluate SoundTrAD (within the overarching RtD methodology).
- Design SoundTrAD: synthesise versions of SoundTrAD, evaluate them and iterate this process. To focus specifically on features that SoundTrAD will provide and what it will support as a method, including:
  - Capturing the different perspectives of AD designs such as the display’s behaviour over time and the interface event to sound mapping.
  - Capturing the rationale underpinning design decisions.
  - Supporting the iterative refinement of AD designs.
  - Enabling the early prototyping of sounds.
  - Accessibility and support for novice auditory display designers.
  - Computer-based tool support for the method.
- Evaluate a final version of SoundTrAD with the target user-group. Identify further design potential, in order to stay true to the RtD mentality and explore further levels of detail/features suitable for further conceptual blending.



## 1.3 Thesis Outline

- Chapter 1: Introduction.
- Chapter 2: A literature review of related work alongside a reflection on where the contribution of this research fits within this wider context.
- Chapter 3: An account of how the approach taken sought to bring together soundtrack composition and design for auditory display, inspired by the theory of conceptual blending. The presentation of a model to represent parallels between the two and a subsequent methodological framework for SoundTrAD. The chapter provides an overview of the research methods employed throughout the thesis and development of SoundTrAD. This involved a mixed methods approach, research-through-design and the use of both qualitative and quantitative research methods.
- Chapter 4: An account of a pilot evaluation of an early version of SoundTrAD for both feasibility and usability.
- Chapter 5: The development of SoundTrAD. Specifically, the exploration of how the different method stages of SoundTrAD can integrate alongside ideas of how functional uses of audio in a soundtrack can parallel functions of audio in an auditory display.
- Chapter 6: An evaluation of SoundTrAD using numerical rating scales to assess it combined with thematic analysis to provide a more in-depth exploration of the use of this iteration of the method and tools.
- Chapter 7: Further refinement of SoundTrAD including the exploration of suitable terminology and categorisations that can be used to support the designer when utilising audio.
- Chapter 8: Discussion of a final development and evaluation of SoundTrAD and demonstration of its success. This includes an evaluation with novice end-users and the demonstration that soundtrack composition provides a framework that a novice can access to support the design of ADs.

- Chapter 9: Discussion of the findings. A reflection on the research methods and implications for further work.

## 1.4 Associated Publications and Presentations

MacDonald.D, & Stockman.T. Lowering the barriers to the creation of interactive auditory displays: an experimental investigation, ISON (interactive sonification workshop) December 2016.

MacDonald.D, & Stockman.T. The overview of a method and supporting toolkit for creating auditory interfaces, based on principles of soundtrack composition in Proc. of ICAD (Student Think Tank), July 2015.

MacDonald.D, & Stockman.T. Towards a Method, Techniques and Tools to Support the Development of Auditory Displays. Workshop Position Paper for Engineering Computing Systems (EICS), Rome, 2014

MacDonald.D, & Stockman, T. Basing a Toolkit to Support Auditory Display Design on Soundtrack Composition in Proc. of CMMR, Oct 2013.

MacDonald.D, & Stockman, T. The Development of a Method for Designing Auditory Display Based on Soundtrack Composition in Proc. of ICAD, July 2013.

University College London, BCS Academy of Computing. The 9th London Hopper Colloquium. Poster Presentation. May 23rd, 2013.

MacDonald.D, & Stockman, T. Toward a Method and Toolkit for the Design of Auditory Displays, based on Soundtrack Composition. In Proc. of Human Factors in Computing (CHI) 2013 Extended Abstracts, April 27 May 2, 2013, Paris, France.

## Chapter 2

# Literature Review

Throughout this PhD the primary research question was to investigate what soundtrack composition can bring to the design of auditory displays, with the aim to develop SoundTrAD; a method and tool for designing auditory displays.

In order to contextualise the research reported in this thesis and put forward the case in support of the need for such a method and tool, this chapter reviews relevant work and information that the reader can reference in order to understand the disciplines drawn upon in this thesis. The chapter comprises two sections. The first section 2.1 overviews soundtrack and section 2.2 details auditory display literature.

## 2.1 Soundtrack Composition

### 2.1.1 Why Film Sound?

It has been argued that sound was incorporated into film in order to cover up the noise of the projector (Weiss & Belton, 1985). The 1920's saw (or heard) the arrival of sound to cinema. Whilst independent film makers and entrepreneurs attempted to integrate sound and film, it was not until A, T &T and RCA, two large technological firms at that time developed technology to support this, that it became mainstream practice (Gomery, 1985). A, T &T and RCA developed sound recording and production equipment that the two major studios in America (Warner Bros and Fox) utilised. These technological developments supported the application and use of sound which, from that point on, had widespread use.

However, attempts had been made previously to use sound and film. In the

1890's Thomas Edison developed the Kinetophone, a device for producing sound used by customers to view a 'peep show'. Although not an attempt to synchronise film and sound, this still represents a very early use of sound to accompany and enhance the visual on some level.

What is clear is that sound brought something to film and, through emerging applications in this area, technology and practice developed into several standard procedures and technical uses that we still see today. It is fair to state that there are certain conventions that form a basis of the use of sound in film, as well as common practices within the film industry that are fundamental to soundtrack composition. These are outlined and discussed in the following sections.

### **2.1.2 Functions of Sound in Film**

Film sound serves to support narrative by communicating intentions, past events, future events, states of an object, types and properties of an action, mood, emotions, time, place, thoughts and feelings of a character (Beauchamp, 2005). Sound can be used to reinforce and augment meaning and as Lipscomb and Tolchinsky observed, it is 'undeniable that a film score, in its typical role, serves to reinforce, alter, and/or augment the emotional content of a cinematic narrative' (Lipscomb & Tolchinsky, 2005, p.3).

### **2.1.3 Types of Film Sound**

A soundtrack is made up of dialogue, music and effects, known in the industry as DMEs. When a sound 'belongs' to the story and image it is said to be diegetic because there is fidelity between what the audience is seeing and what the audience is hearing. Non-diegetic sound refers to the sound that does not belong to the story. For example, whilst the audience might hear a rich orchestra accompany their on-screen protagonist, nowhere within the story or on the screen is there an orchestra. Of course this has been mocked for comic purposes. Mel Brookes for example, had his hero come across a seated live orchestra as he rode across the mid west on his horse in his 1974 film *Blazing Saddles*.

Another type of sound that is used is ambient sound (ambient sound is made up of the sounds that belong to a given space or location). This involves recording

sounds from the scene or set to give an enhanced feeling of presence in the space. Finally, there is Foley (covered in more detail in the section below) which is the creation and syncing of sound effects to the movements of on-screen actors. In summary, the main sounds included in a soundtrack are dialogue, ambience, sound effects (SFX), Foley and music.

## **Sound Fundamentals**

Film academics Bordwell and Thompson outlined a few fundamentals of sound and its acoustic properties that are important to its relationship to film (Bordwell & Thompson, 1985). They acknowledged that, whilst there are multiple acoustic properties that relate to film, they focus on popular, familiar properties common to the listener experience. A selection of familiar properties are given below:

*Loudness:* How a listener will perceive the intensity of a sound. It is a subjective sense that is formed as a result of how listeners' perceive the amplitudes of vibrations in the air. Often the louder the sound, the closer it is perceived to be. Loudness also has impact on characterisation and often volume is manipulated for impact and shock value (Beauchamp, 2005).

*Pitch:* The perceived frequency of sound vibrations. The perceived high and low of a sound. In film, pitch is used to distinguish one sound from another. It is also used for characterisation and dramatic effect (Beauchamp, 2005).

*Timbre:* Harmonic make-up of a sound to give it a 'colour' or tone. It is characterised by the different strengths of frequency content.

*Space:* Referring to the physical location of the source of the sound in relation to the listener. In film, if sound 'comes' from an object or character in the story-space then this is diegetic (as described above). If the sound is outside of the story world then this is non-diegetic.

*Rhythm:* Refers to the movement or pattern of sound (be it music or non-musical sound) over time. It can be used to add tempo and pace to a scene. Rhythm can be used to synchronise a visual with audio and a change in rhythm can shift expectations (Beauchamp, 2005).

In summary, manipulations of loudness, pitch, timbre, space and rhythm can all be used to affect the intention and meaning of any type of sound; albeit music,

speech or a sound effect. Essentially, these fundamental properties of sound can be used creatively to produce, alter and manipulate meaning in the overall soundtrack.

#### **2.1.4 The Three Listening Modes**

In his seminal book on film sound, Chion referred to three types of listening and the importance they have in relation to film sound: Causal listening, semantic listening and reduced listening (Chion, 1994). Causal listening involves listening to sound in order to gather information about its source or cause. The sound can compliment a visual, or, when the source of the sound is not visual, then sound can be used to supplement this visual.

Semantic listening relies on a code or language to interpret the sound. Examples include Morse code or the spoken word. Reduced listening focusses on the properties and traits of the sound itself, independent of a cause. Chion argued that reduced listening is important to film sound because listening like this can open up the possibilities of the sound as a compositional medium. He states that, ‘the emotional, physical, and aesthetic value of a sound is linked not only to the causal explanation we attribute to it but also to its own qualities of timbre and texture, to its own personal vibration’ (Chion, 1994, p.30).

#### **2.1.5 Techniques and Technology to Create Soundtracks**

Listed below are a series of techniques that are used in the early stages of producing a soundtrack. These techniques have been selected as it is felt that they support fundamental approaches to creating a soundtrack and are widely used (Davis, 2010; Holman, 2010; Sonnenschein, 2001; Beauchamp, 2005; Yewdall, 2003).

##### **Spotting**

Spotting refers to the process of going through the film and deciding where the sound will go and what it will sound like (Davis, 2010). Timings are allocated to each identified place (cue) and during the session it is likely that the music editor will take notes regarding each of these cues. The notes are then used to generate a blueprint and in turn, to generate a cue sheet. The cues are often named after the narrative event to which they are synced (Beauchamp, 2005).

## **Cue Sheets**

Cue sheets are the main means by which sound editors communicate the layout of their work to the human mixer (Holman, 2010). The cue sheets list changes throughout a performance and the cues are marked out in a time-based format. Cue sheets are organised with columns to include notes on important footage or time-code numbers corresponding to the start. As, Yewdall observed, a cue sheet is ‘simply a road map of intent’ (Yewdall, 2003, p.23). Interestingly, cue sheets are organised with tracks represented vertically, with time flowing down the sheet. This is the opposite of editing systems, in which time flows horizontally. Each of these is due to the history of editing and mixing; editors worked on benches where the tracks flowed horizontally, but consoles are organised with channel strips aligned vertically, one per track (Holman, 2010).

## **Foley**

Foley is the art of creating and synchronising human sound affects to the on-screen action. It is the recording of the use of props and materials to produce an imitation of sounds that are themselves, for some reason, difficult to record during live action.

The art of Foley was invented by Jack Foley whilst he was working at Universal Studios in 1914. Whilst watching a projected picture, he and his colleagues started to make sound effects in time with the silent film as it rolled. Specifically, adding footsteps to capture subtle movements. This worked well and soon became common practice, known then as ‘direct-to-picture’ (Yewdall, 2003, p.2). Shortly after, a dedicated room with the props and Foley pits (open boxes containing materials such as sand, gravel, water or rice for example) was employed. This dedicated room was known as ‘Foley’s Room’ and soon became the Foley stage. This is what it is called today all over the world.

The Foley artist’s job is typically done by one or two persons, who spot the picture with the supervising Foley editor, gather props, and perform for the recording.

The Foley editor prepares the cue sheets, attends the recording sessions, works with the Foley recordist on track layout and aesthetic recording issues. After the recording has been made, the recording is given to the Foley editor, who adjusts each of the tracks on a digital audio workstation. This detailed stage of editing involves

moving the recorded sound in relation to the picture.

## Mixing

The mixing of a soundtrack involves working with all of the different audio tracks, albeit music, speech or sound effects. Often this is done using a digital audio workstation (DAW) and requires multi-tracking (Holman, 2010).

### 2.1.6 Interaction and Novel Approaches for Film Composition

There have been recent explorations into the use of gesture as a technique for end-users to place sounds on a timeline (Black, 2010). Their research and development work was inspired directly by the motion and direct manipulation of everyday objects, involved in the traditional art of Foley. The end-users were also the focus of research by Callum, Sorensen, and Brown (2008), with their publication that outlines early developments of *MetaScore*, a visual interface that provides the user with control and synchronisation of parameters for the creation of generative film music. The interface supports the user in composing film music using high-level descriptions of ‘compositional intent’ through features such as volume, orchestration, pitch, texture and melodic continuity.

‘Q-Sketcher’ (Abrams & Bellofatto, 2002) provides a tool and method for the different stages of composing music for film. The method and tool is modular, made up of three different method stages with the aim to develop human-computer interaction (HCI) tools to support creative work. Q-Sketcher uses the concept of an ‘idea-space’ to capture ideas. The composer can input their ideas as scribbles, notes, sketches and ideas played on a keyboard, for example. In order to support method flow, Q-Sketcher also incorporates the idea of an ‘integrated content palette’ (a database of ideas that the designer can search through at any point). This supports the designer’s ability to organise their ideas alongside musical materials. To manipulate the ideas Q-Sketcher supports high-level control over the audio as well as detailed, low-level editing.

Currently, *Xhail*, a company based in Ireland <sup>1</sup> are developing a means by which modules (‘stingers’) of sound can be manipulated by the user and adapted to create

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<sup>1</sup><http://www.xhail.com/team/> - accessed 24th May 2016



bespoke soundtracks. The work in this area highlights the importance of working with a potential non-linear narrative (such as in gaming, for example). This work illustrates a compositional approach to soundtrack that can cater for non-linear narrative, whereby events within the narrative can happen in different orders and the modules of sound can be composed and re-arranged to suit this. This enables real-time interactions to affect the unfolding narrative, yet still provide a means for the sound to ‘work’. The sound needs to integrate and function whether its purpose is to draw attention to a particular object or action at a specific time, or even go unnoticed. It can enhance the mood or establish a location, or even provide a smooth ambience between scenes.

## **2.2 Auditory Displays**

This is an area of research that is multidisciplinary and moves forward with input from researchers and practitioners from a wide variety of backgrounds. The field of auditory display is large and a comprehensive review is beyond the scope of this thesis. The Sonification Handbook however does provide a relatively recent and detailed review of the field (Hermann et al., 2011b).

The review presented here of related work in the auditory display area comprises seven subsections. The first subsection 2.2.1 provides understood definitions of auditory display, the second subsection 2.2.2 offers a chronological overview of the development of the field of auditory display and sonification. The third subsection, 2.2.3 reviews specific techniques, the fourth section 2.2.4 lists and examines the toolkits that have been developed, the fifth subsection 2.2.5 explores the different approaches to auditory display creation. The sixth subsection 2.2.6 reviews available methods and section 2.2.7 goes on to review those perspectives on auditory display design that have specifically sought to draw on ideas from how audio is used in the arts, aesthetics and specifically ideas from soundtrack composition.

### **2.2.1 Overview and Definitions**

Auditory display (AD) can be described as an overarching term that includes the representation of information as sound in some capacity. Important to the design and use of an AD is the consideration of the user and the data that is being mapped and

represented through sound. To an extent terminology is adaptable when it comes to defining AD and as Kramer observed, the line between auditory data display and auditory interfaces is somewhat non-distinct (Kramer, 1994).

An interface is described as a two-way connection that supports communication between two systems; typically a human user and a technical product (Peres et al., 2008). The interface is important because it mediates the interaction between an entire system and the user and therefore represents everything in the system that the user comes into contact with, albeit physically, conceptually or perceptually (Benyon, 2010). When sound is used to mediate this interaction, the technology used to represent this sound and the treatment of the sound involved, combine to form an AD. Specifically, this involves the use of sound to communicate messages, monitor processes, display data and enhance the user interface (Kramer, 1994; Kramer & Walker, 2005). Further still, ADs represent the potential that sound has to support human activity and communication with technical systems as well as aid the exploration of complex data (Hermann, 2008).

There are established techniques for representing information. These include, audification to enhance signals — a review of which can be found in chapter 12 of *The Sonification Handbook* Dombois and Eckel (2011), — auditory icons to represent every day objects and activities, a review of which can be found in chapter 13 of *The Sonification Handbook* by Brazil and Fernström (2011) and earcons to represent information that cannot necessarily be associated with a visual, a review of which can be found by McGookin and Brewster (2011) in chapter 14 of *The Sonification Handbook*. More recent explorations include the techniques of Morphocons (Parseihian & Katz, 2012), Musicons (McLachlan, McGee-Lennon, & Brewster, 2012) and Spearcons (Walker, Nance, & Lindsay, 2006). These approaches are reviewed and exemplified in detail in sections 2.2.3.

Sonification is another term that is used in connection with the use of sound to present data. A number of techniques have been proposed for the direct mapping of data to sound including parameter mapping sonification (PMSon), a review of which can be found in chapter 15 of *The Sonification Handbook* by Grond and Berger (2011) and model-based sonification (MBS) (Hermann, 2011). Some or all of these techniques can be used in combination to provide sonic representations of

interface elements and data to form an AD. The particular techniques chosen will depend on the function of the interface, the task at hand, the intended users and the designer’s individual choices.

Hermann’s model that can be seen in figure 2.1 <sup>2</sup>, outlines the relationship that sonification bears to data, interaction, and the mapping technique involved in mapping data or information to sound, as further detailed in section 2.2.3. These mapping techniques that branch off sonification (in figure 2.1) include audification, auditory icons, earcons, parameter mapping sonification, model based sonification and a final category of ‘novel techniques to be discovered’. Therefore, and although this is not demonstrated in this picture, an AD would refer to the audio that is produced as a result of this relationship. The five techniques portrayed in this figure are accounted in more detail in section 2.2.3.

Hermann’s model illustrates the placement of the user in relation to the auditory display. Therefore, at this point in the chapter there is a short overview of how people listen, as this is central to understanding users and how they interact with ADs.

## **Modes of Listening**

The study of psychoacoustics provides a good starting point for understanding how people perceive sound. This section discusses evidence from previous work that underlines the importance for interface designers of understanding the different ways users listen when designing sound to support human-computer interaction (HCI).

Psychoacoustic studies largely involve looking into how listeners perceive simple sounds. However, the study of ecological psychoacoustics pays particular attention to the complex sounds that are often used in real-world auditory displays (Walker & Kramer, 2004). The authors point out that an important consideration for the design of ADs is the environment in which the display is heard as well as the knowledge, experience and expectations of the listener. This has become a current topic of interest among AD researchers. This is most recently demonstrated in work by Droumeva and McGregor (2012) who studied the impact that both context and modes of listening have on the perception of ADs.

There is a difference between hearing and listening. On a simple level, hearing is

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<sup>2</sup>Taken from [sonification.de/son](http://sonification.de/son). Checked on 27th June 2016

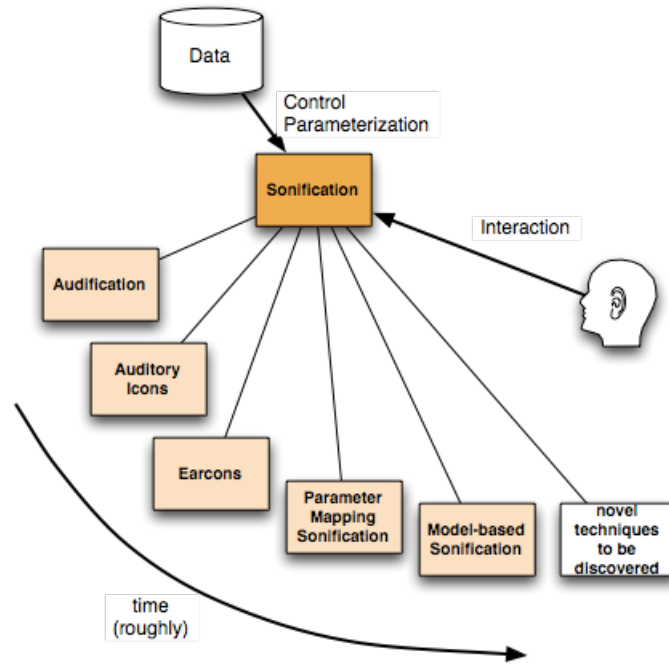


Figure 2.1: Thomas Hermann’s model of sonification and auditory display.

a passive activity whereas listening is an active activity whereby a listener intentionally attends to a sound in order to extract information and meaning (Vickers, 2011). Everyday listening is a term that was coined by William Gaver when designing the *Arkola System* (Gaver, 1989). Everyday listening can be seen through the lens of ecological theory (Gibson, 1986) whereby the environment is seen as important in

human development and learning. Specifically, the ecological view is that the environment provides patterns of optic, acoustic, and other information that determine the nature of the affordances of objects and events (Gibson (1986) in Neuhoff (2004, p.191)).

Everyday listening is centred on the principle that in everyday situations people pay more attention to the source of the sound, rather than the attributes of the sound itself. As a result, properties of the source of the sound become important such as the size of the object producing the sound, its type or its material. Gaver used this as a guiding principle for the conceptualisation and design of auditory icons, a technique employed for representing objects and events in the interface, a more detailed discussion of this form of sonification can be found in section 2.2.3. Everyday listening is the opposite to what Gaver referred to as musical listening, which involves a person listening to the properties of the sounds such as pitch, intensity and location. Gaver’s modes of listening are similar to previous work around listening in relation to musical composition, specifically *Musique Concrete* (Schaeffer, 1967), environmental soundscapes (Schafer, 1977) and soundtrack for film (Chion, 1994).

In what can be seen as being related to listening, Thomas Hermann refers to passive and active sounds (Hermann, 2011). Passive sounds, he argued, can communicate information about the environment and come from an external source, which is not directly caused by the listener’s activity. In contrast, active sounds are the direct result of the listener’s actions and directly relate to a physical activity. Listed examples by Hermann include the ‘rustle of clothes while moving, the clip-clop of footsteps, the soft hiss of breathing, or contact sounds in response to direct or indirect manipulation of physical objects’ (Hermann, 2011, p.401).

### **2.2.2 History of Auditory Display Development**

As mentioned, an AD refers to the representation of data using sound. It is important to acknowledge that this is not a new practice. Early examples of AD include the Geiger counter, where radiation levels are represented through audible ‘clicks’ and changes in pitch. Other examples include a stethoscope which also sonifies, or perhaps more specifically, audifies data, in as far as a patient’s body signals or chest

sounds vibrate the diaphragm of the stethoscope, creating acoustic pressure waves which travel up the tubes to the doctor's ears <sup>3</sup>.

Similarly, a bat detector works by 'audifying' the signals to human hearing range. For an example the reader is referred to chapter 12 of the sonification handbook (Dombois & Eckel, 2011) and specifically the link found at the following footnote <sup>4</sup>. The focus on AD as an academic field was first addressed in 1992 when Gregory Kramer organised and encouraged contributions to the first international conference on ADs (ICAD) in Santa-Fe. This led to the publication of a seminal book on the topic that is widely referenced today (Kramer, 1994). Following this, the ICAD conference series became regular and increasingly more established and is still run annually <sup>5</sup>. However, whilst the conference saw research into techniques, tools, approaches and methods for AD and sonification, important work just pre-dated the ICAD conference series; earcons (from the year 1989) and auditory icons (from the year 1990), both of which will be reviewed in section 2.2.3.

### **Early Stages of Maturation of the Field**

In 2005, the journal ACM Transactions on Applied Perception produced a special 10-year anniversary publication of the best papers from the first ten years of the ICAD conference series, edited by Kramer and Walker (Kramer & Walker, 2005). The special issue contained updated commentaries from the original authors. This work highlighted the fact that a number of application areas for AD were becoming established. What follows is an overview of these areas as well as reference to some of the more recent work that has addressed these areas since 2002.

#### ***Monitoring:***

This refers to the continuous and real-time monitoring of a process or situation using sound. In 1990 Gaver and Smith used audio to monitor a shared work industrial environment (Gaver & Smith, 1990). Their *SharedARK* system was a large virtual simulation of a work environment to support collaboration that used sound to represent user interactions, ongoing processes and represent location. The *ArKOLA system* (Gaver, Smith, & O'Shea, 1991) was a specific application of the *SoundArK*

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<sup>3</sup><http://www.dictionary.com/browse/stethoscope-> checked 19/7/16

<sup>4</sup><http://sonification.de/handbook/index.php/chapters/chapter12/>

<sup>5</sup><http://www.icad.org>

system that simulated a soft-drink bottling plant. *ArKOLA* was made up of nine machines that all made individual sounds to represent their state. The sound design challenge was to blend these sounds to make sure they could all be heard and attended to individually.

Ambient soundscapes were used for the peripheral monitoring of stock market data (Mauney & Walker, 2004) whereby complimentary ecological sounds were used to represent percentage changes in the values of stocks. Audio has also been used for the monitoring of other processes including patients under anaesthetic (Sanderson, Liu, & Jenkins, 2009), network status (Malandrino, Mea, Negro, Palmeiri, & Scarano, 2003), software program debugging (Vickers, 2004), activity in the New York subway (Rubin, 1998) and to assess real-time business processes (Hildebrandt & Rinderle-Ma, 2013).

#### ***Desktop and Portable Computers (Mobiles):***

The application of audio to the desktop was first explored by Gaver (1989). The *SonicFinder* is considered to be the first interface that utilised auditory icons to represent objects and actions in the desktop. Actions such as selecting, dragging, and copying files, opening closing folders, selecting, scrolling and resizing windows and putting files into the trash-can were represented sonically. These sounds were parameterised to communicate size and material of the virtual sound-producing objects. The audio was used in compliment to the on-screen visual icons. Brewster, Wright, and Edwards (1994a) created a sonically enhanced scroll bar and Blattner, Sumikawa, and Greenburg (1989) employed earcons to represent desktop processes.

The use of audio in mobile devices is becoming increasingly important, particularly in the context of mobile and ubiquitous technologies, for example through the use of multiple application programming interfaces (APIs), such as Android and iOS, for example. Guidelines for the latter can be found on the Apple Developer website <sup>6</sup>. Research and development in this area includes exploration of how users can interact with wearable computing devices (Brewster, 1999, 2002). There has also been work inspired by the way users utilise and interact with their phones in different contexts. For example, there has been exploration into how sounds can be embedded in the phone to support sporting activities (Barrass, 2013) and the devel-

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<sup>6</sup><https://developer.apple.com/ios/human-interface-guidelines/interaction/audio/>

opment of *Shoogle* to explore the relationships between gesture, movement, sound and mobile phone use (Williamson, Murray-Smith, & Hughes, 2007).

### ***Sonification of Physiological Signals and Movement:***

Audio has been used to represent real-time electroencephalogram (EEG) signals (Baier, Hermann, & Stephani, 2007). A review of which can be found in the work of Valjamae et al. (2013). Applications within this include the use of audio for health monitoring and diagnosis and also cross overs with the use of audio for sport.

The Sonification of movement for physiotherapy and sport is an upcoming area of research interest. Consequently, significant research has been carried out in recent years. For example, Vogt, Pirr, Kobenz, and Robert (2009) worked with a system to track human movement and used to trigger sound files. The sounds were dependent on user preferences and context in an attempt to address aesthetics and performance. Hermann et al. (2011a) sonified the movements of aerobics to enable visually impaired users to participate in aerobic exercise. Barrass (2010) investigated six interactive sonifications of accelerometer data captured from participants using indoor gym equipment. Schaffert and Mattes (2012) and Schaffert and Gehret (2013) studied the use of audio to enhance rower's movements and evaluated whether acoustic feedback could improve performance levels for elite athletes. Barrass (2013) created 'sweatsonics' a mobile phone application to explore sonification in outdoor spaces. His work focussed on the principle of embedding sonifications in mobile phones in order to cater for the context of use. Again The Sonification Handbook, chapter 21 by Höner, Pauletto, Röber, Hermann, and Effenberg (2011) reviews work in this area.

Also relating to this area, 2014 saw the first symposium at York University, UK, exploring the sonification of health and environmental data (Pauletto, Cabridge, & Rudnicki, 2014).

### **Recent Approaches and Conferences on Auditory Displays**

Whilst the early developments in AD research largely focussed on the challenges of mapping information and data to sound, the maturation of the field saw an increased focus on different approaches, methods and frameworks to support the designer. In particular, work began to take into account new interaction paradigms, as some



of the later examples above highlight; for example Barrass’s work on embedding sonification and Williamson’s *Shoogle*, an application where a shaken mobile phone would trigger audio in order to indicate the status of the mobile phone — such as the presence of received text messages. Research also began to explore ideas around the different applications, and context of use for the AD. More detail will be given on some significant perspectives on auditory display design in section 2.2.5. However, in order to be consistent with the general chronological overview of AD and sonification, that this section describes, attention is now drawn to the focus on interactive sonification that began with the first in a series of workshops on Interactive Sonification that took place in Bielefeld in 2004 <sup>7</sup>. The aim of the workshop, which still runs tri-annually, is to explore new ways of interacting with data and the role of the user in the design, generation and use of ADs.

Other conferences such as Audio Mostly <sup>8</sup> and HAID <sup>9</sup> (haptic audio interaction design), have also been established in light of increasing focus on the role of the user in the design of interactive technologies. The latter for example, specifically addresses the role of haptics and audio for the design of multi-modal interfaces.

### 2.2.3 Techniques for Employing Sound in the User Interface

The use of earcons and auditory icons was established in the late 1980’s and so existed before Gregory Kramer established the ICAD community. Similarly, even before the emergence of AD as a research area in the early 1990s, tools were beginning to be developed to support various aspects of AD development. These are described in section 2.2.4. However, before that the most common and established techniques are reviewed in relation to the role they serve within AD.

#### Auditory Icons

Auditory icons are ‘everyday sounds designed to convey information about an event through analogy to everyday sound producing events [...] allowing us to listen to computers as we do to the everyday world’ (B. Buxton, Gaver, & Bly, 1994, p.1). They bear a direct relation and association to the process they represent (Kramer,

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<sup>7</sup><http://interactive-sonification.org>

<sup>8</sup><http://audiomostly.com>

<sup>9</sup><https://www.interaction-design.org>

1994). It has been argued that they are based on the concept of everyday listening and the idea that people describe sounds in terms of the objects or events that caused them (Mynatt, 1994).

A set of design criteria was produced by Mynatt (1994), who made the point that auditory icons in the interface must be evaluated as a cohesive set. In other words, the sounds must work together. She evaluated a series of auditory icons by assessing 15 object and action concepts from graphical interfaces. Participants were asked to say which sounds they associated with the desktop concept. It was found that participants expected the sound to relate to a direct manipulation task, for example, they expected there to be a direct correlation between action and sound. What follows is a list of the guidelines produced by Mynatt:

- Select short sounds;
- evaluate how identifiable they are with free-form responses;
- test perceptual mappings away from the interface in order to limit confounding factors from other parts of the interface;
- address learnability of the auditory icons that are not immediately recognisable;
- evaluate potential problems in masking and psychoacoustics;
- evaluate task completion as well as affect of long term use.

Gaver applied auditory icons to his previously referenced *ArKOLA* system (Gaver et al., 1991). This was followed by the use of auditory icons in the *Sharemon* system (J. Cohen, 1992) to portray file sharing activities on an Apple network.

## **Earcons**

*‘Art is to icons as music is to earcons’* (Blattner et al., 1989, p.15).

Earcons are short, structured musical messages used in the human-computer interface. Like auditory icons, they were initially designed to represent and provide feedback about different objects, operations or interactions within the human computer interface (Blattner et al., 1989; Blattner, 2000). However, unlike auditory

icons, they are useful for representing those entities that do not have a visual counterpart. They need to be learned and rely on systematic compositional approaches for their construction. Earcons are made up of patterns that form motifs or modules that in turn belong to families.

Initially earcons were designed to enhance desktop widgets. However, earcons can also be used to inform the user about background information and unseen processes in the interface (Brewster, Wright, & Edwards, 1994b; Brewster, 1998). A set of initial design principles were established by (Brewster & Wright, 1995). These include information on timbre, register, pitch, spatial location and intensity.

The application of earcons for unseen processes is, as previously mentioned, useful in those situations where the user can not fully access information; either due to a visual impairment or because their line of sight is restricted. Similarly, there is evidence that earcons can off-set the limitations caused by the reduction in visual screen space which is more-often-than-not the case with ubiquitous and mobile technologies (McGookin & Brewster, 2011)).

When discussing the future directions that the design and application of earcons could go in, McGookin and Brewster (2011) proposed developing methods to help designers further in their creation: firstly they proposed that more work is needed on designing earcons where the meaning of what they are communicating is more implicit and demonstrative. Another area that they proposed could benefit from more investigation is the development of hybrid displays whereby earcons and auditory icons can be systematically combined in one display. For clarity, the next section 2.2.5 gives a brief overview of the work that has been done in this area.

Blattner et al. (1989) proposed four different ways in which motifs can be manipulated to form earcon families. The four types of earcons they propose are: *One-element earcons*, *Compound Earcons*, *Transformational Earcons* and *Hierarchical Earcons*.

***One Element Earcons*** are used to communicate one piece (parameter) of information. The important design consideration for one-element earcons is that they cannot be further decomposed. Several one-element earcons can be used, of course, but they are not related to one another. Each sound has an individual quality and its meaning must be learned individually.

**Compound Earcons** are created by concatenating one-element earcons to create more complex messages. McGookin and Brewster (2011) described that they are analogous to forming a phrase out of words. The earcons are played sequentially to form a sentence, but in order to limit the potential duration of the compound earcon, it is recommended that they do not exceed 4-notes in length (Blattner et al., 1989).

**Transformational Earcons** are constructed using a set of rules, which maintain a consistent set of parameter mappings between data and individual sound types. Using this approach, it becomes possible to create many combinations of sounds through the application of a few rules. This approach reduces the amount of learning required of the user, since it is the rules that need to be learned rather than the individual sounds. An example is McGookin’s set of earcons to represent the cost of theme park rides in which timbre is used to represent the cost of the ride and pitch is used to represent the intensity or level of excitement of the ride.<sup>10</sup>

**Hierarchical Earcons** are also constructed around a set of rules. Each earcon forms a node of a tree and thus inherits the properties of the node above it in the tree. For example a non-pitched sound may represent an error and the next level may alter the pitch or the rhythm in order to represent the type of error (McGookin & Brewster, 2011). Messages are derived through a modular, hierarchical and systematic structure of inheritance and, once again, the rules provide a structure for learning what it is that is being communicated.

**Musical Earcons** are designed taking into account the power that music has to communicate meaning. As discussed, designing earcons depends on the structuring of non-speech sounds through combination, inheritance and transformation in order to develop an auditory language of representation (Blattner et al., 1989). The success of earcons depends upon the listeners learning the structure of the sound. However, it was argued by Leplâtre and Brewster (1998) that the interface designer should not need musical knowledge and that unlike earcons, ‘music transmits information without requiring its structure to be understood’(p.229).

Hankinson and Edwards (1999) and Hankinson, John and Edwards (2000) explored the use of musically-based grammar for the design of earcons. They explored

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<sup>10</sup><http://sonification.de/handbook/index.php/chapters/chapter14/>

ways in which combinations of small musical units can form larger musical phrases with the power to communicate complex meaning. The authors proposed a method for earcon design based on musical grammars. They proposed that earcon designs should avoid using sequences of notes that could be perceived to have a musical melody, as this was thought to be distracting. When defining their earcon grammar, they argued that the same principles of language could be applied to music. Essentially, both are governed by a set of rules that define how basic units of each system can be combined to create larger phrases. For example in music, notes are the equivalent of letters in language, and musical phrases or motifs the equivalent of words. Using these units the authors proposed a musical grammar based on Western tonal harmony whereby chords were designed to represent the units, and chord combinations were used to create either a musical consonance or dissonance. The consonant chords were then considered grammatical and the dissonant chords, ungrammatical. They mapped this musical language to a simple object/action model by choosing four objects; disks, files, printers and text, and decided upon a list of actions to be performed upon them (pause, print, copy and bold, for example). Some of the actions could be performed on multiple objects, such as copy and others only executable on one object. The legal and illegal combinations of interactions were then mapped to the harmonious and dissonant earcons, respectively.

### **Parameter Mapping and Model Based Sonification**

The paragraph below summarises two important approaches to data sonification. The approaches are described below, along with further references for the interested reader.

In order to create a sonification, the designer needs to consider what it is the user needs to accomplish (their tasks) and what parts of the information source (the data) are relevant to the user's task. Additionally, they need to consider how much data the user needs to complete the task, what kind of display to use and how to manipulate the data (Walker & Nees, 2011). It was argued by Hermann (2008, p.2) that in order to be classified as a sonification, the use of sound and data have to conform to certain rules. These include:

- The sound has to reflect objective properties and/or relations in the input

data;

- the ways that the data (and possible interactions) cause the sound to change is defined and systematic;
- the sonification is reproducible;
- the sonification system can be used with different sets of data.

Sonification seeks to translate relationships in data or information into sound(s) that exploit the auditory perceptual abilities of human beings such that the data relationships are comprehensible (Walker & Nees, 2011).

Parameter Mapping Sonification (PMSon) involves changes in data being directly related to changes in one or more properties of the audio signal. A common choice for the property into which changes in data are mapped is pitch. The perceived changes in the audio signal represent changes in the data. Often this is used for monitoring of processes such as monitoring the level of activity on a network or monitoring medical signals such as blood pressure or heart rate.

Hermann (2011) describes model-based sonification as involving the designer creating an interactive virtual model which is used to drive a sonification. The user can then listen to the changes in the sonified output that result from their exploratory interactions with the virtual model. The sonification is therefore continuous and driven by user interaction. This method of sonification tends to support the exploration of large and complex data sets.

#### **2.2.4 Software Tools for the Sonification of Data**

There has been a wide range of toolkits developed to support the sonification of data. It is important to define what makes a toolkit. In some cases it could be hard, for example, to distinguish between a design approach that has implemented a tool to research and test the central design ideas, such as the sonic mapping tool by Coleman, Macaulay, and Newell (2008), and those toolkits that are created specifically for use ‘out of the box’. When creating their general sonification environment SonEnvir (detailed below), DeCampo, Frauenberger, and Holdrich (2004) outlined some general principles that a toolkit should adhere to; it should be able to read a data file in various formats, perform basic statistics, provide basic playback facilities,

support multiple synthesis processes, store sonification designs in human-readable formats, serve to build a library/database of designs and the implementation should be kept open, flexible and as light weight as possible.

A selection of toolkits are listed below in chronological order. This includes details of the aim, implementation, application and evaluation (if applicable) that relates to each toolkit.

- InfoSound (Sonnenwald, Haberman, Keese, Myers, & Bank, 1990). An interface toolkit suitable for creating and placing both music and everyday sounds in the interface. The architecture of the system was made up of 6 components: A sound composition system; a sound storage system; a playback system; an application program interface; a sound generation system and a sound amplification system. They concluded from their development that interface designers not trained in music, found their system difficult to use. They argued that further development was needed to design a system that enabled those developers without musical training to use the system as a result of automatic compositional algorithms or a music library retrieval system.
- LISTEN (Lodha, Wilson, & Sheehan, 1996; Wilson & Lodha, 1996). Developed to be a portable and intuitive sonification tool. The idea was that it was modular, used internal sound generating chips or external sound generating engines controlled by MIDI, could plug into an existing visualisation system and support the principle that a user can modify and extend the tool kit. The interface module supported user input and was made up of simple sliders and has the ability to identify different sound parameters. The control module served as an intermediary between the user input and the data. The data manager module supported the processing of a number of data fields and the scaling of minimum and maximum values to the data. This module fed the data line by line to the controller module which in turn passed it to the mapping module. The sound mapping module mapped data to pitch, duration, volume and location. Timbres could be selected by the user along side the ability to design their own transfer functions. Finally, there was the sound device module which initialised the sound playback equipment. The playback information could be assigned to any platform (through the use of MIDI).

They created a video with 3 demonstrations to show it at work.

- MUSE, a ‘musical sonification environment’ (Lodha, Beahan, Heppe, Joseph, & Zane-Ulman, 1997) . A development of LISTEN in order to explore the use of musical sounds (they claimed that non-musical sounds can cause fatigue). The aim was to develop a general-purpose sonification tool for the creation of musical and non-fatiguing sounds. They also aimed to be flexible in the mappings to cater for subjective choices and wide a community of users. The system was programmed in C++ and comprised a musical generation component and a graphical user interface (GUI). The objective of the GUI was to provide an interactive environment for a user to map data to sound and was made up of simple menus, sliders and buttons. The toolkit provided six different options for mapping the data to sound using rhythm, tempo, timbre, volume and pitch (melody) and harmony. Their explorations saw MUSE being used to explore uncertainty in iso-surfaces and volumetric data. It was concluded in Lodha et al. (1997) that further work was needed.

Indeed, it is not clear from their paper whether any user studies were done using the toolkit and what the specifics were of the mapping of data to sound. Was it more musical and less fatiguing, for example? MUSE was developed into the toolkit MUSART, which is detailed below. Interestingly, in their paper documenting MUSART Joseph and Lodha observed, in relation to MUSE, that ‘the complexity of the musical concepts combined together made it difficult to extract meaningful information through multivariate sound mapping’ (Joseph & Lodha, 2002, p.1).

- SONART, a ‘sonification application and research toolkit’ (Ben-Tal et al., 2002). The objective was to provide researchers with options to explore parameter mapping with the same high-level control offered in visualisation packages. Three components: synthesis toolkit, parameter engine and the scheduler. The aim was to provide platform independence, adaptability and extendible synthesis and sound processing capabilities. They argued that LISTEN and MUSE had limited scope and so SONART aimed to provide the designer with broad synthesis options. Every sound synthesiser had a set of parameters to define



how the sound should be generated. The user creates dynamic sounds by changing these parameters with a set of controllers. The data is fed in and then a set of synthesis parameters can be used to generate the output. The user can further mix parameters and layer sounds together using a simple and intuitive interface. They tested the toolkit by using it to map oceanographic and financial data to a formant filter that synthesises human-like vowel sounds. They concluded that the project laid the foundations for an open-source, collaborative project with a wide range of scientific applications.

- MUSART, a ‘Musical audio transfer function real-time toolkit’ (Joseph & Lodha, 2002). This extension of MUSE was intended to become more accessible to a wider user group. It was designed to be used for multiple applications, and provide engaging and non-fatiguing, familiar sounds. The aim was to support the user in creating a personalised AD from mapping each data dimension (of either multivariate and univariate data sets) to different musical components. Musical ‘concepts’ such as register, pitch, timbre, chords, duration, silence, loudness, beats, and panning were used to create melodic sound maps. The toolkit combined the use of musical concepts and synthesis algorithms in order to create an environment which, as Joseph and Lodha stated, ‘allows any person to generate the most simple or complex auditory display regardless of music, scientific, or sound synthesis background’(Joseph & Lodha, 2002, p1). They exemplified the use of MUSART by arguing that it could be used to build musical auditory maps to explore seismic volumes used for detecting areas for drilling oil. The mappings between the information and sounds were limited to ten musical components in order to support ease of use.

In the paper they provide three scenarios with example mappings. First, data to pitch using a western scale. Second, combining duration and pitch. Third multiple tracks with different timbres. They describe the mappings but it is unclear whether any user studies were carried out and whether any person can generate an AD regardless of their background.

- The Sonification Sandbox (Walker & Cothran, 2003), is a multi-purpose, multi-platform tool that allows the user to map several datasets to volume, pitch,

timbre and spatialisation. The user can also have full control over the minimum, maximum range, polarity and the scaling of data. The user can also add context to their design (a reference click track, repetition or constant tone that represents the minimum, maximum or average quantities of the data.) Walker and Cothran (2003) designed the Sonification Sandbox to be usable by the ‘student, school teacher’ and ‘average researcher’(p.1). It is based on the previously mentioned MUSART by Joseph and Lodha (2002), which evolved from MUSE which in turn, evolved from LISTEN. MUSART differs from the Sonification Sandbox in that it has musical elements, whilst the Sonification Sandbox focusses more on the addition of context. It can be used to create auditory graphs from data files, read as comma separated value (CSV) files, and it can export MIDI files. Novice to expert designers can use the Sonification Sandbox because it has limited mapping possibilities and uses sound generators that can be driven using MIDI. There is no detail of an evaluation or description of sounds in detail. It is described in this paper as work-in-progress. However, more recently researchers such as Nees (2012) have applied it to explore correlations between auditory and visual modes of learning. It is still also possible to download and use the Sonification Sandbox from The Georgia Tech. Sonification Lab <sup>11</sup> (see footnote for a link to download).

- The Interactive Sonification Toolkit (Pauletto & Hunt, 2004). The objective of this system was to let a user process and scale datasets and rapidly change the sonification method. They argued that it is important to focus on the interaction method as much as it is on the data that is being sonified. The user interaction can be used to ‘sift the data, tune the parameters, and focus on the areas of interest’ (p.1). It was developed in Pure Data <sup>12</sup> and the user could upload a dataset for it to be organised into columns and rows. The user can define the minimum and maximum values of the data and map this to pitch, loudness, duration and timbre. In their studies Pauletto and Hunt (2009) used sensor data from physiotherapy and helicopter flight analysis. The authors described that user studies were under development to investigate how

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<sup>11</sup><http://sonify.psych.gatech.edu/research>

<sup>12</sup>PD is an open source visual programming language. <http://puredata.info>

the nature of the interface and the interaction style affects the perception of the data in sound.

- SonENVIR (DeCampo et al., 2004) is a generalised sonification environment that provides basic data handling, data processing, sound synthesis, mappings and real time interaction. It was built using audio programming languages Pure data and Supercollider <sup>13</sup> with the aim of being usable by researchers from multiple scientific domains. The sonification techniques involved looking for similarities between a scientific domain, and the sound domain. For example, looking at effective ways of representing seasonal changes in rainfall using suitable properties of sound.

However, Beilharz and Ferguson argued that ‘one of its drawbacks is the significant amount of knowledge required to use its implementation in SuperCollider’. They observed that ‘it is quite technically ambitious, and also seems to incorporate spatialisation methods for the IEM Cube spatial playback system’ (Beilharz & Ferguson, 2009, p.2).

- Sonifyer (Dombois, Brodewolf, Friedli, Rennert, & Koenig, 2008). The aim of this system was to build software that can be used by researchers and amateurs alike. The authors argued that there needs to be more focus on usability and distribution within the field of sonification. They argued that researchers should think about Apple software design, and its accessibility due to the ease with which it can be downloaded and installed (they offered iTunes <sup>14</sup> as an example). Dombois et al. (2008) used Sonifyer to sonify EEG data using frequency modulation (FM) synthesis and sound visualisation techniques to create, what the authors called, ‘aesthetic presets’.
- AeSon (Beilharz & Ferguson, 2009) a toolkit for the design of aesthetically pleasing displays. Built in Max/MSP <sup>15</sup> and Processing <sup>16</sup>. The design of the toolkit was inspired from their insight into how visual design principles can be transposed onto the design of auditory displays. The authors supported

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<sup>13</sup><https://puredata.info> and <http://supercollider.github.io>

<sup>14</sup><https://www.apple.com/uk/itunes/> - accessed 22 August 2017.

<sup>15</sup><https://cycling74.com/products/max/>

<sup>16</sup><https://processing.org/>

this creation with the argument that aesthetic design can enhance the communicative power of the data it supports. So, additionally, AeSon permits user-control over the audio parameters. They created the sonification mapping based on the principle that sonification generally uses a specified number of data-points represented as sound events (usually notes) which are presented at a constant rate or tempo. For the audio design they argued that musical aesthetics typically require the use of musical scales and harmonic movement through chordal changes. Adding that Western musical scales such as minor or major scales, with non-regular interval leaps can also provide a frame of reference that the listener can use to orient themselves with respect to the key of the music. From the paper it is not yet clear that the toolkit has been evaluated.

- AWESOME, ‘Audio Workplace Simulation Machine’ (Fagerlönn & Liljedahl, 2009; Liljedahl, 2009; Fagerlönn & Liljedahl, 2010). A web based tool that offers user control and ability to manipulate audio with a specific scenario in mind. The challenge was to design sounds given a user context (outside of laboratory, for example) and with the idea that the sound will exist in a context. Participants could respond to a visual scenario using sound by changing the tempo, rhythm and articulation in real-time. The tool was designed to help designers link sounds with and characteristics of a user situation. The user context and situation is represented on the screen by an image or video and a text string. The auditory stimulus is manipulated using radio buttons organised in columns placed in the lower part of the screen. Each column represents a unique sound parameter that can be manipulated separately in three steps or levels. In the pilot study users could manipulate 3 audio parameters: number of tones, harmonic complexity and register. They presented participants with 5 driving scenarios ranging from ‘urgent to less urgent’. The evaluation focused on the usability of the interface and the chosen sounds. The sound options were restricted, and so the question remains how they chose the sounds and the rationale behind the mapping.
- SDT, ‘sound design toolkit’ (Monache, Polotti, & Rocchesso, 2010). A toolkit for explorations in sonic interaction design. Designed as a front-end applica-

tion, the system made use of virtual Foley pits (see section 2.1.5) for sonic interaction design research and education. SDT supported the embedding of audio into interactive artefacts, using sensors and physics based sound synthesis. Built in the audio programming language Max /MSP, the physics-based sound models are implemented as externals and patches and can be combined together and linked to external physical objects. There are three parts to the synthesis: 1. Auditory perceptual relevance, 2. Cartoonification (simplifying the underlying physics and emphasising relevant aspects) 3. Parametric temporal control for natural expressive articulation. The sound models represent interaction between 2 physical objects (resonator-interactor-resonator). These include rolling, breaking, bouncing and crumpling, squeaking, breaking and rubbing sounds and frying, dripping and pouring sounds. All of the sound choices relate to the concept of ecological hearing proposed by Gaver et al. (1991). The toolkit has been applied in work by Monache et al. (2010) at the HAID (haptic audio interface design) conference to explore ‘connections between narrative discourse, aesthetic attributes and sonic dynamic properties of interactive commodities’(p.5). The investigation focussed on how particular expressive qualities, that can be obtained from a discussion on film sound examples, could be transferred to the the physics-based approach in the SDT (Monache et al., 2010). This is discussed in more detail in the following section.

The toolkits described above all aim to support ways that data can be easily scaled and mapped and auditioned. An observation or question that arises from the formation of this list is how well do these toolkits serve to support the novice designer or researchers from different backgrounds? There is a lack of information about usability evaluations, as the emphasis of the reported research appears to be on the tool development rather than a reflection on the outcomes that the tool produces.

The aesthetics and success of the actual display produced is not documented in the above reviewed work, it is more geared toward reflecting on what the tool can do and how it is built. There are also questions around how well the design patterns of the tools are captured; something that DeCampo observed as important in the design of a toolkit (DeCampo et al., 2004). It is possible to see that as the toolkits

developed (LISTEN to MUSE to MUSEART, for example), the mappings became limited in order to try and address issues around accessibility. It is also clear that increasingly aesthetics and user-centred design, are becoming more important in the design of the toolkits and the choices of mappings.

### **2.2.5 Perspectives on Auditory Display Design**

In the early to mid 1990s, as the whole area of HCI was taking shape, Andrew Monk and others edited a book which sought to capture the different perspectives that were being adopted in research and the development of products with a strong focus on usability (Monk & Gilbert, 1995). The book covered such diverse approaches to HCI as formal methods, ethnography, cognitive psychology, and discourse analysis. It could be argued that AD design is at a broadly similar stage of development as HCI was at that time, the process having taken so much longer in the case of AD design due to a much lower critical mass of researchers and developers working in the field. This section reviews the different perspectives to AD development that have manifested themselves in the literature and ADs over the last 25 years.

It is first worth noting that, when reviewing various perspectives on AD design that have been proposed in the literature, the distinctions between what are termed ‘approaches’, ‘methods’ and ‘frameworks’ often seem to be somewhat blurred. Brazil (2009) reviewed a set of methods and frameworks that are suitable for the early stage development of ADs. To meet the criteria for their review, the methods and frameworks had to be considered accessible, easy to carry out and focus on conceptual design stages. For example, they reviewed methods and frameworks that centred on prototyping without an apparent focus on the part of the developers on a usability evaluation.

An investigation into the available guidance and the current practices of AD designers was carried out by Frauenberger et al. (2007) and Frauenberger and Stockman (2009). The authors carried out a survey involving 86 participants from a general HCI background. The survey aimed to investigate the approaches that the HCI community took to AD design and the sources of any support or guidance. They concluded that, whilst the majority of participants saw some benefit of using audio in the interface, there still existed the view that audio is a medium with which

many designers felt unfamiliar, lacking guidance and unclear how to use. Interestingly, the authors discovered that the AD design process was largely considered to be a craft-based exercise, regarded suitable for musicians or professional sound designers. To exemplify this, one of the participants of their survey observed that the creativity involved in sound design and composition may be hard to capture. As a result, the authors argued for a framework that unified the different approaches taken for the design of auditory displays and a means to capture and transfer this design knowledge.

The approaches were based on the workshop that Barrass and Frauenberger delivered at ICAD in 2008 called ‘Recycling audio displays’, in which they categorised design rationale and the different perspectives on how to design ADs (Barrass & Frauenberger, 2009). The different perspectives, alongside a brief explanation, were published in Frauenberger and Stockman (2009) and are as follows:

- Perceptual: an approach that looks at the hearing abilities of human beings.
- Ecological: approaches that explore everyday listening.
- Contextual: considering the context of the AD and the user.
- Task driven design: taking into account the tasks supported by the audio.
- Semiotics: exploring the language used to describe audio.
- Compositional design: music theory, structures and compositional practices.
- Exploratory design: designers can explore the design space and options available to them based on existing knowledge.

The perspectives listed below identify viewpoints reflected in more recent AD literature. Recent research has seen, for example, exploration of approaches to AD development and evaluation that take into account where the AD will be used, collaborations between scientists and artists and the role that the end user can take in the design and evaluation processes. It is intended, therefore, that the perspectives listed below address this recent work.

## **Narrative-Based Design**

Designing for HCI often employs scenario-based design (Carroll, 2000). Scenarios are concerned with the tasks and the users involved within the interaction. They are stories with narratives that explore what potential users of a given system do when engaged in a particular activity (Carroll, 2000). Importantly they take into account the user and the context in which the action takes place. Scenarios involve settings, and have a plot involving a sequence of actions and events, things that actors do, things that happen to them. Storytelling techniques have developed in HCI as a means of information exchange between technical and non-technical groups (Barrass, 1996a). Scenarios account an instance of an interaction with a system. The use of scenario and narrative to inspire sound design for human-computer interaction is well established. The affordances of the desktop metaphor were observed by Back and Des (1996). They argued that every component within the desktop has its own story to tell and that narrative takes the metaphor a step further by including time into its function which means that behaviour becomes possible. Barrass (1996a) also developed a database of ‘EarBenders’ (stories about peoples’ interactions with sound) and used them to provide useful structural information for the design of ADs, based on ways that people hear sounds. An exploration into ways narrative sound design strategies from film can be applied to the design of interactive commodities was carried out by Hug (2009). They claimed that finding narrative in ‘natural’ sounds helped create aesthetically fitting mixes of everyday fictional sounds. Progressing from this, Monache et al. (2010) used the sonification design toolkit (SDT, as referenced in the previous section) to explore connections between narrative, aesthetics and the use of sound in interactive objects. Specifically, they focussed on film sound and how any expressive qualities, that could be gathered from a discussion on film sound, could be used by the physics-based approach of the SDT.

## **Action (task) and Event-Based Design**

Closely tied in with the use of scenarios and narrative to support the design of ADs is the process of identifying actions and events within an HCI scenario in order to map them directly to sound. Brewster and Wright (1995) developed the event-status method to support the analysis and categorisation of events and states of the



interface in order to decipher what feedback is needed to present them. Specifically, the event-status method proved useful in their view for identifying and sonifying information that remained hidden from the user in the interface. Events were seen as something that happen at a discrete point in time and remain action dependent. In contrast, the state referred to any persistent value that the user could employ to perceive the given state of the system and remains action-independent. Brewster and Wright (1995) used the ‘event-status analysis’ to offer design guidelines for a set of earcons. They argued that sounds that represent events need to occur at the time of the event and be demanding in nature. Whereas the sounds used to represent status need to be sustained and possible to ignore. In addition to these guidelines, the authors proposed that sounds can be either static or dynamic depending on whether the feedback changes during presentation.

### **Ecological and Contextual Design**

Providing the rationale for design decisions is useful in making design approaches reusable and explicit (Dix, 1998). One such angle on this approach is to make explicit the context in which the AD is to be used. Relating to this are recent developments in AD design that draw inspiration from the argument that the mobility and ubiquitous nature of contemporary technologies need to be taken into account (Hug, 2009). Hug argued that there is little knowledge about how to design audio for ubiquitous and mobile technologies. Specifically, how a particular meaning is formed in a specific context. Coleman et al. (2008) asked designers to consider the different sounds within the display in combination with the different sounds, external to the display, which remain audible while the display is presented. This approach to designing ADs also caters for how the differing sounds (those within the interface and those of the environment) mix and combine and the effect they have on one another when combining to form the auditory environment. Specifically, this approach adopts principles of acoustic ecology, a field of research that concerns the effect and composition of the acoustic environment. In relation to AD design, acoustic ecology has shaped the investigations of researchers such as (Droumeva, 2005; Droumeva & McGregor, 2012). The authors argued that acoustic ecology can offer insight into how listeners perceive and interpret ADs within their acoustic environment.

Recently, Tunnermann, Hammerschmidt, and Hermann (2013) have explored the idea of blended sonification where the sounds of the user’s context can be taken into account when designing the AD. Furthermore, the natural ambient sound from the environment can be augmented and manipulated to increase the information bandwidth. Two examples the authors give is the sound of a computer keyboard in use which is modified by information about the weather. Or the sound of a knock at an office door which is modified according to whether the occupant of the office is in or out.

### **Compositional Design**

Frauenberger and Barrass ran a workshop at the 2008 ICAD conference to explore the re-usable design knowledge that exists amongst the ICAD community (Barrass & Frauenberger, 2009). Compositional design was one approach that was found to be significant, due to the fact that composers are frequently asked to contribute to the design of ADs in order to increase the aesthetic of the result (Barrass & Frauenberger, 2009). However, the authors observed that capturing the expertise of composers was difficult, due to the creativity that is inherent to the approach.

The use of music as a communicative medium in relation to auditory interfaces was explored by Leplâtre and Brewster (1998). They posited that there were not enough guidelines for non-musical designers. Similarly, musical tones were used in the interface by Edwards (1989) in his *Soundtrack* word processing system for blind users. Tones were used to identify different desktop objects and could, if the user required, be re-emphasised through the use of speech synthesis. The use of music to create an *auditory screen* also formed part of the work of Brewster et al. (1994a). In their work they used earcons to develop a musically enhanced scrollbar. An ascending and descending tone was used to represent the position of the bar as it moved up or down, respectively. This was found to reduce the task performance time of the users.

Taking on compositional and organisational principles directly from music was one approach to designing musical interfaces that was adopted by Alty, Rigas, and Vickers (2005); Alty (1995). They developed the *Audiograph* system which communicated graphical information, such as squares, rectangles, triangles and lines to

blind users through musical sequences. Alty et al. (2005) also developed *Caitlin* a system where musical motifs were used to represent brackets at the start of a block of code. At the end of each block of code the motif was then reversed and repeated in order to represent the closing brackets respectively. Other musical conventions and techniques used included the use of a major or minor chord to represent the TRUE or FALSE outcome of a boolean expression and the use of a constant drone to represent the progression as the programme executed loops. Cleverly, the authors nested the musical motifs in ways that paralleled the structure of the code. For example, the users could identify if an IF statement was nested within a FOR loop. Using similar techniques for the evaluation of this system the users were asked to rate the annoyance factor of having music play in the interface. They found that ‘about half’ of the participants found the music to be moderately annoying, while it was found to be acceptable by the other half.

In a further evaluation Alty et al. (2005) also found that, provided detailed numeric data was not being communicated, music was successful in transferring information. They summarised that music was good at communicating information and providing that this is the main criteria for success then it is beneficial to use music. They also compared the use of music to the use of speech using these systems. Their studies revealed that speech, unlike music, can become tiring when listened to over a lengthy period and that music is more enjoyable to listen to. They concluded that the varying components that make up musical structures such as pitch, rhythm, timbre and harmony provide good information sources that can reveal more information than speech.

Experiments using music in the interface were also carried out by Rigas, Alty, and Long (1997) when investigating how to communicate the contents of a software engineering database. Rigas et al. (1997) examined whether it was possible to integrate musical messages in order to create one musical message with multiple meanings using musical techniques such as stereo positioning, rhythm and pitch. They found this compositional structure and technique to be successful. Interestingly, they found that the designer needed to invoke some sort of metaphorical association in the listeners mind between the data being presented and the musical technique being used. For example, that of increasing pitch relating to increasing

numeric value.

### **Compositional Approaches: combining audio**

The understanding of how different sounds combine in an AD was considered by Albers with the investigation of how auditory icons and sonification can be used simultaneously within the interface (Albers, 1994). Similarly, Sonnenwald et al. (1990) created a system that allowed designers to combine music and sound effects for the interface for both a telephone network simulation and a parallel computation simulation.

### **Exploratory Design**

Frauenberger describes exploratory approaches as those that allow the designer to explore the design space (Frauenberger & Stockman, 2009). An example of this approach is DeCampo's design space map which aimed to make implicit design knowledge explicit and available for reflection, discussion and learning (DeCampo, 2007). Designers could navigate a physical map of design techniques and sonification strategies based on the type of data they wanted to sonify. Structural properties of the data ranging from discrete to continuous could help decipher which technique to use.

Added to this category is research that has explored the role of the end user in the design process. Recently Wolf and Fiebrink (2015) have explored how an end user can iteratively 'generate, explore and refine' a sonification design. End users can work with models for soundscape, data and sonification and take control of the sonification system. To date they have a prototype system called the Environmental Soundscape Creator (ESCaper) which allows the user to work with their soundscape using a GUI. Users can choose how accurate they want the mapping to be and which data they want to sonify or they can let the system make the decisions for them.

The Science By Ear workshop which has run twice at Graz University (2006 and 2015<sup>17</sup>), has been examining how domain experts can work together. Gourdazi and Vogt (2015) have been working with scientists from a range of different disciplines. In their paper accounting the 2015 workshop with data scientists, sonification experts

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<sup>17</sup><http://iem.kug.ac.at/projects/workspace/projekte-bis-2008/composition/science-by-ear.html>

and programmers, Gourdazi and Vogt (2015) observed that there is still a scepticism as to how useful sonification is as way of representing data.

Other exploratory ideas have included research into the working processes of designers in real-world settings, away from the lab and with commercial needs to match. For example, Jeon (2010) looked at the role of the auditory user interface (AUI) designer within a commercial electronics company. Other approaches have explored how sound can be designed whilst the user interacted with the scenario they were designing for (Liljedahl & Fagerlön, 2010). Similarly, Hug (2009) asked designers to act out scenarios to inspire ideas for sound design.

Fascinatingly, Barrass (2014) wrote a paper for the SoniHED conference that reflected on his work using blood pressure data to design bespoke ADs. Specifically, Barrass (2014) printed a 3D acoustic bowl using blood pressure to create each layer or ring of the singing bowl. This made each bowl unique to the person at that moment in time. The work was inspired by the concept of ‘self-knowledge through numbers’ and the idea that the user’s data can be used to construct the story they tell about themselves.

### 2.2.6 Methods for Auditory Display Design

In this thesis a method is defined as a series of coherent steps that aim to support the design, creation and evaluation of an AD. Evidently, methods such as those reviewed in Brazil (2009) and the tools mentioned in section 2.2.4 support the designer in going some way towards creating a display, in that they focus in detail on a particular design stage. However, for clarity, a distinction is made here between the approaches and tools that support a specific stage of creating a display (albeit the conceptual, prototyping, mapping or evaluation process) from those methods that attempt to support the designer through all of the design stages. From gathering the requirements of what is needed, to the conceptual stage through to the final part of evaluating an AD. It is argued here that important to identifying something as a method is a coherency between the stages that in turn give the method user’s the ability to iterate and re-visit design stages and steps.

Stephen Barrass’s **TADA** (task-oriented data-sensitive method) is a well-established and referenced method for AD design and data sonification (Barrass, 1996a, 1996b,

1997).

The design process integrates task analysis, a database of sound examples, a rule based design aid and interactive design tools. The method has 4 phases:

- Scenario (situation) description.
- Requirements (situation) analysis.
- Representation design (example lookup).
- Realisation (design synthesis).

The scenario is a short story about the information processing activity, the purpose of the activity and the interaction and organisation of the information. The scenario is documented and then key features are extracted recasting the scenario as a question with the principle that ‘useful information is the reply to a question’ (p.4). Information concerning the storyteller, the question, the answers and the elements all provide the coupling between the story and the next step of Situation Analysis.

The situation analysis is a detailed examination of the situation description in terms of task, information and data structure. The requirements are used to look up examples from a database (EarBenders) of 150 stories about every day listening, which are ranked by similarity of information structure with the requirements.

The taxonomy of mappings provided in the EarBenders database was generalised from the literature of psychoacoustics and data visualisation. Once the data is organised, the designer can use ‘personify’, an interactive tool to work with the sound. The design is then realised with the representation of the audio on a display device. In principle a model of the display can be reproduced on different display devices.

**PACO** (pattern design in the context space) by Frauenberger and Stockman (2009) offers a methodological design framework for AD design. The method supports an exploratory approach to AD design in that end users can explore the design space and refer to and incorporate existing knowledge when designing their ADs. It was concluded by the authors that PACO facilitated the transfer of design knowledge and good practice from experts to novices through design patterns.

### **2.2.7 Approaches to Auditory Display Design that draw on Soundtrack Composition**

This section addresses the research that has gone into exploring how ideas from film sound can be used in the design of ADs, sonifications and interactive artefacts. The section takes into account certain important elements of soundtrack composition as structuring mechanisms and organises associated research into the following categories: aesthetics, audio treatment, tools and techniques.

#### **Aesthetics in the Design of Auditory Displays**

The discussion on aesthetics is placed at this point in the review because it is felt it bridges into a discussion of why the insights of music composers, sound designers and soundtrack composers are considered valuable for the design of aesthetically pleasing displays.

In their chapter in *The Sonification Handbook*, Barrass and Vickers, 2011, compare visual design to sonic design by stating that, ‘where graphical visualization draws on graphic design [it is possible to] draw on sound design for commercial products and film sound in the next generation of ubiquitous everyday sonification’ (Barrass & Vickers, 2011, p.165). They go on to compare composers with film composers, claiming that whilst composers do not have to focus on functionality and accessibility (unless they opt to do so), film composers have to be aware of the function of the audio and how listeners perceive it.

The authors argued that ‘aesthetics (sensuous perception) is the common thread between sonic art and sonification’. They claimed that they both depend on a stimulation of the senses in order to successfully convey meaning and that there is an unnecessary wall that divides the two disciplines.

The link between aesthetics and user satisfaction was explored by Leplâtre and McGregor (2004). The authors argued that the function and aesthetics of the AD cannot be separated due to the fact that the nature of the tasks involved in the interaction effect the aesthetic value of the AD. They observed that the relationship between the context in which the AD is used and the sound itself, is likely to effect the perceived aesthetic nature of the interface and subsequent user satisfaction. In their paper the authors present a list of auditory design parameters that can aid the

investigation into the aesthetic nature of a display. These include:

- Homogeneity of the design: to consider the overall impact of the display and ways that the different sound elements can work together and be played and combined in different orders and sequences whilst not compromising the harmonic unity of the display.
- Blending of sounds: to create a smooth mix of the sounds in order that there are not abrupt changes between the different sounds in the display
- Density of sounds: limiting the perceived density of the sounds in order to limit annoyance. Particularly when working with rapidly changing sounds in the display.

An investigation into ways that electro-acoustic music can be used to represent multivariate data was carried out by Diniz, Deweppe, Demey, and Leman (2010). The authors proposed that this would add aesthetic value and subsequently validate the output. They argued for Pierre Schaeffer's concept of a sound object (Schaeffer, 1967) as a 'base structuring concept' because it permits multiple layers of complex information to be manipulated under one 'abstract structure'. Similarly Vickers and Hogg (2006) presented an argument for the study of *Musique Concrete* when considering the design of ADs and sonification. They proposed an *aesthetic perspective space* into which sonifications and musical compositions can be mapped. They argued that sonifications should be seen as works of art in order that they benefit from the application of aesthetic practices used by composers.

Paul Vickers and Hogg pointed out that, 'many sonifications have suffered from poor acoustic ecology which makes listening more difficult, thereby resulting in poorer data extraction and inference on the part of the listener' (Vickers & Hogg, 2006, p.210).

### **Parallels between the use of Audio in Films and Interfaces**

For her doctoral research, Grice (2006) explored the use of music in the interface. She compared the use of sound in film with its use in interfaces. She claimed that in a film setting music provides elements that could also prove useful within a computer interface setting. These included:



- Editing continuity - which could be useful when switching between windows in a desktop.
- Motifs for reflecting characters - useful for identifying which window is active or useful as a way to introduce a particular theme, algorithm or principle.
- Enhance action - emphasize something on a screen.

A toolkit for explorations in sonic interaction design (Monache et al., 2010) utilised the idea of Foley pits to be used in sonic interaction design research and education as a means to support the embedding of audio into interactive artefacts. A detailed investigation into the parallels between soundtrack composition and auditory display design, that formed a significant part of this research, is documented in chapter 3, section 3.4.

### **Approaches and Techniques for using Film Music in Auditory Display Design**

A direct insight into how the functions of film music could benefit computer-based design was explored by Cooley (1998). Cooley argued that, like a soundtrack, using music in interactive systems can help expand screen space, draw attention to both on and off screen events as well as provide characterisation and emotions in HCI. When referring to the use of sound to enhance learning in ‘computerised instructional environments’, Bishop and Sonnenschein (2012) argued that sound is somewhat under utilised. To overcome this, the authors recommend four approaches from the ‘best practices’ of film industry sound design. The recommendations are as follows:

- Firstly, they propose that like sound design, the sound used in computerised instructional materials could be used to support storytelling by helping learners ‘acquire, organize and synthesize’ the materials under study (p.7). Interestingly, they pointed out that selecting or composing the right sounds involves carefully ‘harmonizing the subject matter, learner characteristics and objectives of the instructions being developed’ (p.7)
- Secondly, they point out that when designing soundtracks, sound designers often begin their processes with an initial reading of the script. From this

they ‘listen out for’ objects, actions, environments, emotions and physical or dramatic tensions that can be ‘fleshed out auditorally’ using the various sound types (which they describe as music, speech and sound effects). They then argue that the instructions for computerised learning environments can also be identified for these key ‘storytelling elements’ (p.8) through a collaborative process (between sound designer and media developer). A process that involves identifying the objectives of the instructions in terms of the nature of the subject to be learned (cognitive strategies, intellectual skills or attitudes), the primary and secondary learning objectives for the instructions, the type of instructional strategies to be used (explorative or direct) and the identification of any potential difficulties. At this point it then becomes possible to match these elements up with sounds considered suitable for emphasising the main concepts involved and the main organisational structures of the instructions.

- Thirdly, the authors argue that like sound designers, designers of audio for an instructional product should understand and utilise the way people listen to sounds. The authors reference the modes of listening presented by film theorist Michel Chion; reduced, causal and semantic (Chion, 1994).
- Lastly, the authors argue that like sound design for films, designers should be systematic about how they incorporate sounds. Sound designers work within a framework and literally map out along a time line where particular sound groupings (voice, music, sound effects) will be placed as the story unfolds. They propose that humans learn through a process of ‘selecting, analysing and synthesizing’ which can be seen as analogous to a film’s beginning, middle and end.

## **Summary**

This chapter has provided a review of the development and current practices of film soundtrack composition, and the history, tools, perspectives and methods applied in the development of ADs. The chapter has reinforced Stephen Barrass’s and Christopher Frauenberger’s argument that the knowledge of how to build a good auditory display is still ‘hidden in the experience of the experts and creativity of the artists’ (Barrass & Frauenberger, 2009, p.1). Soundtrack composition has been

established over 100 years; there are clear systems and structures, such as those documented by Chion (1994) and Sonnenschein (2001) for example, which support dissemination and education. However, AD is a relatively young area of research. New methods and perspectives are being established and explored. It is hoped this thesis will investigate, and contribute work toward these areas, through exploring what soundtrack composition can bring to the design of ADs.

## Chapter 3

# Approach and Research Methods

As noted in chapter 1, section 1.1, in order to develop SoundTrAD this research needed to address a ‘wicked problem’; the bringing together of soundtrack composition and interface design. Drawing together these considerations, two specific questions were asked at this stage in the research: 1) What happens when methods for interface design meet approaches to soundtrack composition? The interface designer has certain goals and techniques, as does the composer, but what do these two disciplines have in common? 2) Are there any significant differences between the two disciplines that need to be acknowledged in order to successfully create SoundTrAD?

In order to help address these questions, this chapter starts by giving an overview of the theory of conceptual blending, before selecting and reviewing existing techniques and approaches for creating both interfaces and composing soundtracks. As a result of this, and influenced by the potential benefits of creating a ‘blended space’ from the two disciplines, section 3.4 describes how a method structure and fundamental steps for SoundTrAD were proposed as a result of combining and drawing parallels between ideas from both soundtrack composition and interface design. Specifically, it proposes how SoundTrAD could have four method stages based on established stages for interface design and that within these stages could reside method steps that are made up of identified parallels between established steps from soundtrack composition and steps for interface design.

Table 3.1 illustrates the parallels between soundtrack composition and auditory interface design, based on the literature review. The table presents four major stages to interface design and four stages to soundtrack composition and steps within these stages. Figure 3.3 then goes on to present the ‘blended space’ that was synthesised as a result of exploring these two disciplines, in the form of method stages and steps that can make up SoundTrAD.

Finally, this chapter provides detail research through design (RtD) and related methodologies that were adopted in order to frame an iterative design approach for the development of SoundTrAD and its evaluation. This follows on from chapter 1 which detailed how RtD was felt to be a suitable overarching methodology to adopt, due to its ‘intrinsic ability of bringing together many ideas through the process of integration and composition’ (Zimmerman et al., 2010, p.137).

### 3.1 More on Conceptual Blending

Chapter 1 briefly discussed how conceptual blending is the construction of meaning as a result of exploring two disciplines (Fauconnier & Turner, 2003a).

In their recent studies on designing natural and intuitive interfaces (Bødker & Nylandsted Klokmose, 2016) described conceptual blending concisely as ‘the ability to combine multiple conceptual spaces into one emergent one, called a ‘blend’. They argued that this blend ultimately ‘shares and combines traits of the input spaces, but also provides an emergent structure for reasoning and acting beyond the individual input spaces’ (Bødker & Nylandsted Klokmose, 2016, p.2539).

This is similar to Fauconnier and Turner’s argument that ‘a conceptual blend operates in two input mental spaces to yield a third space, the blend’ and that ‘partial structure from the input spaces is projected into the blended space, which has emergent structure of its own.’ (Fauconnier & Turner, 2003b, p.149). Turner demonstrated this idea of a blended space through a simple image, documented here in figure 3.1 (Turner, 2003).

It is important to summarise that the aim of this research was to synthesise a new approach to AD design combining established ideas from both interface design and soundtrack composition. The resultant method, to be called SoundTrAD, may be seen as a blended space into which the two disciplines of interface design and

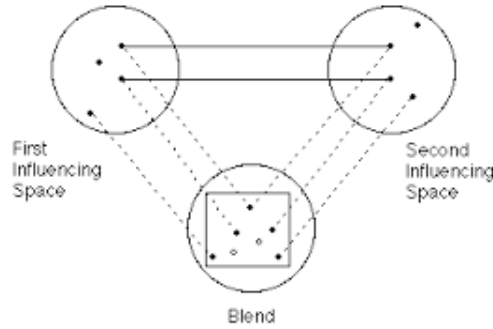


Figure 3.1: Turner’s visualisation of conceptual blending.

soundtrack composition are projected.

### 3.2 A Review of Creating Interfaces

This section provides a review of the stages of interface design that were identified as being relevant to the development of SoundTrAD. These design stages offered ideas, principles and design guidelines to help establish SoundTrAD as a consistent approach to auditory interface design. Given the overall goal of the research, during this analysis, particular attention was paid to concepts in interface development practice that could be seen to parallel practices in soundtrack composition.

#### Function

An interface may be characterised as bi-directional connection that supports communication between two entities; normally a human and a technical product (Peres et al., 2008). The interface is important because it mediates the interaction between an entire system and the user and therefore represents everything in the system that the user comes in contact with, albeit physically, conceptually or perceptually (Benyon, 2010).

#### Design Stages

Existing guidelines for interface design support several methodological stages. These have been applied to interfaces with and without audio. The following stages are not derived from a single source, but from a range of sources on interface development, including Dix and Brewster (1994); Carroll (2000); Benyon and Macaulay

(2002); Peres et al. (2008) and Benyon (2010) and represent a summary of interface stages accounted in those references. The different sources vary to some degree in terminology and emphasis they placed on each of the stages, however, these stages provide a broad structure from which to approach the design of an interface.

### ***Requirements Gathering***

The first of the stages is the requirements investigation or requirements gathering stage. This stage involves identifying who the users are, the tasks to be supported by the interface and the context of use.

### ***Conceptual Design***

The second stage, the conceptual design stage, involves considering the overall form of the interface including the modes of interaction to be supported and how communications between the users and the system are to be organised.

### ***Detailed Design***

The third stage is the physical or detailed design stage whereby the interface is mapped, refined, implemented and prototyped. When discussing these stages of developing interfaces specifically for auditory displays, Peres et al. (2008) point out that in ‘whatever form it takes, the specification should detail how the interface will be organised, how it will *sound* and appear and how it will behave in response to user-input well enough to prototype or implement the auditory task to a point that is sufficient for subsequent development and evaluations’ (p.173).

### ***Evaluation***

Finally, there is the evaluation stage, which involves testing the interface with end-users (Benyon, 2010; Peres et al., 2008).

### **Scenarios and Stories**

The use of scenarios, to capture the details of what users require to do and what interactions need to be supported, has been employed by many HCI researchers, notably by Carroll (2000). The familiarity of scenarios (stories) and their common

use in both soundtrack composition and interface development suggests they should make a good starting point for the development of SoundTrAD.

Scenarios are stories and have narratives that explore what potential users of a given system do when engaged in a particular activity. Scenarios have settings and a plot involving a sequence of actions and events; things that users (or as often defined ‘actors’) do and things that happen to them (Carroll, 2000). More specifically, within an HCI context, scenarios are accounts of people using technology which are made up of descriptions of the user and a description of their tasks. Scenarios may be more or less detailed, for example, they may describe the details of subtasks and include details of how users interact with a system and how the system responds to these interactions.

### ***Task, User and Context Analysis***

An analysis of the scenario, in order to inform the interface design, is known as a task analysis. The analysis of the tasks to be performed, the users or system that performs them and where the tasks (actions) take place is important in creating a user-centred design. Central to this is the user and their point-of-view of the system they are interacting with. Different users have different preferences, goals and expectations. Analysis of the context in which the interface will be deployed is also important. This, for example, could effect design decisions for SoundTrAD such as choice of suitable feedback, or the type of audio or visual that is used to represent the feedback. For example, in their study on office soundscapes, Coleman et al. (2008) argued that auditory interface designers consider the different sounds in the display in combination with the sounds that exist externally to the display and within the context. They showed the importance of paying attention to how the different sounds combine and to the potential masking issues that could occur between sounds when it comes to sound design choices.

### ***Triggers, Events and Status Analysis***

Tasks are essentially user or system actions and both can trigger events (Dix & Brewster, 1994). User interfaces are nearly universally programmed using an event-based paradigm (Dix, Leite, & Friday, 2007). Events are action dependent and have



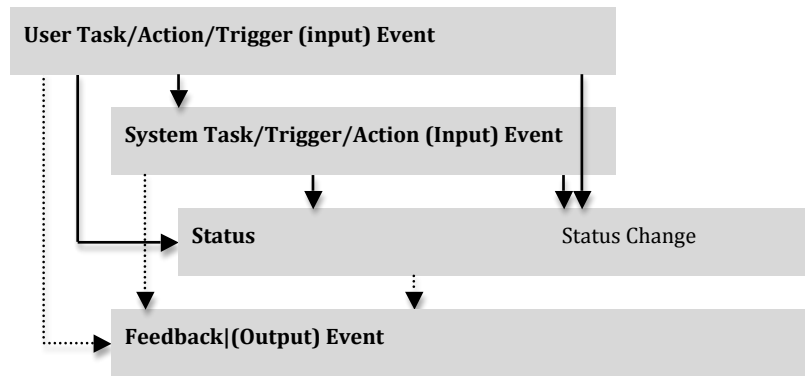


Figure 3.2: Relationship between tasks, actions, triggers and status.

a temporary existence. The initial trigger (task or action) will cause a system event or a representative feedback event in the interface be it visual or audio. Brewster and Wright (1995) referred to the trigger as an input event (such as a mouse click or button press) and to the feedback event as an output event (such as a beep or a light flash).

Events, as mentioned, are action dependent; they are ‘things that happen’ as a result of a user or system action, whereas status is action independent and ‘a thing that always has some value’ (Dix et al., 2007, p.211). However, any given status can be affected by an event which can cause a change in status. Figure 3.2 illustrates the relationship and interchangeability between tasks, actions, triggers, status, feedback and events and is based on the work of Dix and Abowd (1996).

It should be noted that in 2007, Dix updated his model of event and status analysis to incorporate the potential of working with continuous input data from sensors (Dix et al., 2007).

*Sensors tend to monitor status phenomena such as temperature, pressure, sound level. At a low level these sensor values are translated into discrete data samples at particular moments, but unlike the moment of a mouse click, the particular times of the samples are not special times, merely convenient ones to report at. So at a descriptive level, it is inappropriate to regard them as ‘events’ even if they are implemented as such at low-level. Furthermore, the data rates may be very high, perhaps thousands of samples per second so that at a practical level not taking into account*

*their nature as status phenomena can be critical for internal resource usage and external performance and behaviour* (Dix et al., 2007, p.211)

The quotation above illustrates an important distinction and classification between what is considered an event that occurs as part of the user-system interaction and system states which will often be updated through a series of events that occur with a high frequency, which are inappropriate to consider as events from a user-system interaction perspective.

### **3.2.1 Summary and Example**

The above section has summarised interface design with a focus on the different stages, the importance of outlining user tasks and the nature of analysing the events that make up the tasks. Highlighted above is also the importance of considering the interface from the end-user's point of view alongside a context analysis when designing interfaces, both of these as a central part of adopting a user-centred approach.

#### **Example: The Artist Scenario**

Referring back to the example scenario documented in the introduction in chapter 1, it is possible to think about the events that make up the scenario of an Artist, written below, and apply to designing interfaces some of the processes highlighted above.

*The scenario: An Artist wants to monitor live hits to her website whilst painting. Specifically, she would like to know how many people are viewing it at any one time and how long they stay and when they leave. She cannot watch a visual monitor but would like to monitor live or receive updates on request without interrupting her work.*

A designer of an AD to fit these needs might analyse the events in the scenario as follows.

- The Artist turns on the monitoring system.
- Someone logs on to her website.
- Someone logs off from her website.
- She interacts with the monitoring system to have the information updated.

However, the designer may also want to consider the nature of the user and any other events that may exist in this scenario; is it worth considering the noise of her paintbrush, for example? A radio playing in the background or other people in her studio perhaps? This is optional, of course, but mapping out the scenario and the events, actions and context will help the design of the interface and could help produce a more user-centred auditory interface.

### **3.3 A Review of Creating Soundtracks**

The following section provides a review of the functions and principles of creating soundtracks. This review is based on multiple sources including Sonnenschein (2001); Beauchamp (2005); Holman (2010); Ventura (2010); Kalinak (2010) and Chion (1994). The different sources vary to some extent in the way they describe the principles and functions of soundtrack composition, but the review given here draws on what is considered to be the most frequently utilised and widely held principles. Once again, given the overall goal of the research, during this analysis, particular attention was paid to concepts in soundtrack composition practice that could be seen to parallel practices in interface development. A more detailed review of soundtrack composition can be read in chapter 2, section 2.1.

#### **Functions**

As noted in chapter 2, sound in film is used to anchor and engage us with meaning, smooth out editing, enhance and create mood and emotion, illustrate geographical location and historical situation, focus attention on a specific action or object, determine speed and motion and to function as a leitmotif, associated with a specific character or theme (Sonnenschein, 2001; Ventura, 2010; Kalinak, 2010). Furthermore, film music communicates intentions, future and past events, states of an ob-

ject, types/properties of actions, moods, inner feelings and thoughts of a character as well as time and place (Beauchamp, 2005).

### **Design Stages**

Hollywood sound designer David Sonnenschein outlines a methodical approach to creating a soundtrack from the script to the final mix (Sonnenschein, 2001). With this Sonnenschein does not offer a technical account of suitable software, or specific hardware, or mixing or editing techniques, but rather a creative approach to analysing a script and conceptualising, designing and delivering ideas for a soundtrack to the technical team. This includes techniques and methods that can not only aid in the initial decision of where sounds should go (known as ‘spotting’) but also the categorisation, mapping, placement and initial arrangement of suitable sounds. Sonnenschein is clear to point out that, whilst linear, the steps are subject to personal ordering and are not definitive. What is clear, in his suggested approach, is the importance of iteration as part of the creative process and the means by which the composer can be guided and supported at the same time. Sonnenschein also points out that the composer should consider sound from the start of the design process (Sonnenschein, 2001; Bishop & Sonnenschein, 2012).

### **Scenes and Spotting**

Composers will analyse a scene by ‘spotting’ it for places that could be enhanced by audio. Sonnenschein wrote that within every on-screen *character*, *object* and *action* there is potential to generate a sound that can enhance the narrative and story (Sonnenschein, 2001). With the starting point of marking the script, in order to identify key storytelling elements that can be ‘amplified by sound’, Sonnenschein identifies the following ‘voices’ to listen out for; namely by identifying and circling explicit words and phrases: *People*, *objects*, *actions*, *environments*, *emotions* and *transitions*.

### **Fundamental Sound Classifications**

Once the composer has annotated their ideas for sounds, the suggested ideas are classified into categories of dialogue, music, sound effects (D-M-Es). What is im-

<b>Auditory Interface Stages and Steps</b>	<b>Soundtrack Stages and Steps</b>
<b>Stage: Requirements Gathering</b> - scenarios and task analysis with <i>users/actors/characters, events, objects, actions, context</i>	<b>Stage: Spotting the scene</b> - stories with <i>characters, actions, objects, transitions, locations</i>
<b>Stage: Conceptual Design</b> - thinking about interface arrangement, and what parts need sonifying and how it is laid out	<b>Stage: Arranging</b> ideas and cues, sketching, establishing and iterating ideas
<b>Stage: Detailed Design</b> - mapping events to audio	<b>Stage: Composing/Designing</b> original music and sourcing sound samples to map to the cues/events
<b>Stage: Evaluation</b>	<b>stage: Evaluation</b>

Table 3.1: Parallels between audio interface design and soundtrack composition.

portant in a soundtrack is the consideration of how these sounds work together and how they form the bigger soundtrack by relating to one another and to the story being told. Within a film, the soundtrack contains not only the musical score, but ambient sound, dialogue, sound effects, and silence.

To underline the importance of considering the soundtrack and all the sounds that make it up as a whole, Lipscomb and Tolchinsky argued for the analysis of the entire soundtrack because ‘musical sound, dialogue, sound effects, silence, and some sounds that fall in the cracks between traditional categories all exist for the purpose of enhancing the intended message of the motion picture’ (Lipscomb & Tolchinsky, 2005, p.5).

### 3.4 Bringing the Two Together

The above has briefly outlined some of the fundamental processes in creating interfaces and soundtracks. A set of parallels between these activities is proposed in table 3.1. This table illustrates the initial parallels that were identified between soundtrack composition and auditory interface design. These are presented as four larger method stages involved in creating auditory interfaces and composing soundtracks. In these stages reside steps that support these design stages.

		Steps
Stages for SoundTrAD	1. Requirements Gathering	Work with scenarios. Understand users (actors or characters) involved. Think about their context or location. Within the scenario identify events as made up of objects and actions.
	2. Conceptual Design	Layout of interface, arranging events within the scenario
	3. Detailed Design	Mapping events to audio. Choosing, designing or composing suitable sounds
	4. Evaluation	Evaluating and iterating the design and auditioning sounds as part of an iterative design process.

Figure 3.3: A blended Space: stages and steps for SoundTrAD.

### 3.4.1 Similarities

It is clear to see from 3.1 existing similarities between how a film scene and a scenario are analysed. Specifically, the importance that both soundtrack composition and auditory interface design put on identifying and working with actors (users) or characters as part of the requirements gathering stage and spotting stage, respectively. Identifying actions, objects, locations and context is also important to both disciplines. Both disciplines, as part of the detailed design stage and composing stage, respectively, also lay importance on considering suitable audio onto which events can be mapped. Finally, both disciplines depend on the ability to evaluate and iterate their respective design processes.

Figure 3.3 presents an initial coming together of these stages and steps based on these identified parallels. This represents a candidate blended space between the two disciplines and formed the basis of SoundTrAD. The principle method stages are consistent with the stages used for interface design: requirements gathering, conceptual design, detailed design and evaluation stages. This supports the goal of using SoundTrAD to develop auditory interfaces. The finer steps within these stages are synthesised from both disciplines of interface design and soundtrack composition.

### The Artist Example: Testing the Stages and initial Steps of SoundTrAD

The scenario of the Artist in her studio is revisited below. The stages and steps outlined in figure 3.3 are applied to the scenario. This allows various design issues and questions to be identified, both in regards the specific interface to be designed, and the emerging new design method.

The scenario (repeated on this page for the reader's convenience): *An Artist wants to monitor live hits to her website whilst painting. Specifically, she would like to know how many people are viewing it at any one time and how long they stay, and when they leave. She cannot watch a visual monitor but would like to monitor live or receive updates on request without interrupting her work.*

1. Requirements Gathering Stage: work with scenarios. Understand users (actors or characters) involved. Think about their context or location. Within the scenario identify events as made up of objects and actions.
  - User (character/actor): female painter, paints in the studio, likes the radio on?
  - Context/ location: her studio, daytime?
  - Actions: turning monitoring system on and off, painting, listening, someone logging on or off to her website, interacting with the monitoring system to poll the information.
  - Objects: monitoring system, web pages, paint brush, room, icons on her desktop, speakers and possibly a radio?
2. Conceptual Design Stage: layout of interface, arranging events within the scenario.
  - Issue concerning the method: there is an unresolved issue concerning temporal ordering and non-linearity of events as explained in 3.4.2 below.
  - The transitions between the events becomes important, particularly if they are changing orders.
3. Detailed Design Stage: mapping events to audio. Choosing, designing or composing suitable sounds.
  - Question: what sounds are suitable given the gathered requirements?
  - Observation: Issues and considerations around the layout of events and non-linearity (in the sense explained in section 3.4.2 below) will affect the

sound choices and ideas around how they can work together to form an overall display.

4. Evaluation stage: evaluating and iterating the design and auditioning sounds as part of an iterative design process.
  - Question: how can iteration be supported in the design process?
  - Question: specifically, how can the sounds be auditioned?

### 3.4.2 Differences and Incompatibilities

The above section has highlighted similarities and differences between the two design processes, and some issues to be considered in blending them.

#### Issues to consider at this Stage

- It is usually the case with soundtrack composition for film that there is one timeline, with one scenario. However, in an AD, just like a game, there can be many different potential timelines, each with its own scenario. Therefore, SoundTrAD needs to consider how a specific scenario (a use case) can be associated with each interaction design to be sonified.
- In soundtrack it is important to work from Stems whereby the audio is classified very precisely into dialogue, music and sound effects (DME's). No such established convention exists for auditory interface design. It could be beneficial to use such a structure from soundtrack composition in order to address issues around aesthetics, auditioning and transition between events.
- Aesthetics is very important in soundtrack composition and the coming together of many types of sounds to form a whole. Can this be supported in AD design?

Taking the above issues into account, there is a clear need for a story/scenario to be documented. The potential non-linearity of the user-actions and events within the scenario needs to be considered. Transitions between the different events is important and so too is the context in the scenario. The method stages and steps need



to support the designer in iterating their design and auditioning the sound choices. Therefore, the questions remain how SoundTrAD can support these features?

### 3.5 The Aim of SoundTrAD: What Can It Support?

Below are re-listed the set of features that SoundTrAD is intended to provide and what it is intended to support as a method, as documented in chapter 1, section 1.2. However, the desired features have been refined and expanded as a result of the issues identified in this chapter. The exploration of similarities and differences between interface design and soundtrack composition and the questions and issues that the example scenario identified, enabled an updating and expansion of the aims of SoundTrAD as a method and to the features it was to provide.

- To lower the barrier to creating ADs in order to enable novice designers to engage effectively in the AD design process.
- To support the iterative refinement of AD designs. Addressing the recognised need to evaluate as part of the design process.
- To enable the designer (user of SoundTrAD) to complete a prototype/model of their design. Once again to support an iterative design approach and evaluation as part of the design process.
- To support the designer in executing accountable, repeatable steps toward producing a display that communicates whatever it is that was intended to be communicated (Kramer, 1994).
- To capture the different perspectives of AD designs such as the display's behaviour over time. To consider the linearity of the narrative for the scenario and the nature of interaction changing orders. To consider multiple timelines.
- To enable the designer to consider suitable event to sound mapping. To think about the aesthetic in so far as how the different sounds can blend and work together. To consider each sound in relation to the other sounds presented within the scene/display while considering the impact of the audio as a whole composition (Lipscomb & Tolchinsky, 2005). To consider the auditioning of sounds as part of an iterative design process.

- To enable the designer to document their ideas in order to support the referencing and sharing of design rationale. In relation to this, to support them in organising sounds into categories based around different ideas or cues.
- To offer computer-based tool support for the method. Specifically, to support the designer in an iterative design process and working with sounds. Namely, the mapping of events to sounds, the auditioning of sounds and the ability to work with multiple timelines in relation to this.

## 3.6 Research and Evaluation Methods

The work in this thesis made use of research through design (RtD) as an underpinning methodological approach.

### 3.6.1 Research Through Design

Key features of the RtD approach have been discussed extensively by (Zimmerman et al., 2007, 2010) and (Gaver, 2012). Collectively, RtD is seen as a methodology that is suitable to address ‘wicked problems’ or ‘messy situations’ (Zimmerman et al., 2010). These are identified as design problems that are not amenable to conventional scientific exploration. RtD lends itself to addressing these problems because it aims to integrate knowledge and theories from across multiple disciplines in a holistic way. In the case of this project, the contributing disciplines include soundtrack composition, and interface design.

RtD takes an ‘iterative approach to reframing the problematic situation’ and the preferred state as the desired outcome of the research (Zimmerman 2010).

For reasons explained in chapter 1, section 1.1, an essential early part of this research was centred on exploring what was needed. Part of the approach taken was to identify parallels and differences between the two contributing disciplines (section 3.4), to identify aims for SoundTrAD as a method (section 3.5). Another part of the approach was a process of discovery, refinement and the reframing of the problem by undertaking initial exploratory studies (chapters 4, 5 and 6). As new knowledge was gained as a result of this process, it became clearer what should be the content of the SoundTrAD method, and the questions to be explored to develop the method

further became better defined. The later studies in the thesis therefore became more amenable to the application of conventional research methods.

RtD allows researchers to focus on research of the future, a preferred state of the world and an idea of ‘what could be’. As such, RtD is seen as a methodology that can lead the researcher to make contributions to knowledge that may include a series of artefacts in which that knowledge is implicit, and an account of the various methods and approaches employed to get to that stage. The artefacts should be documented and can serve as ‘placeholders’ that present and open up new spaces for design.

Various methods can be employed within RtD. Zimmerman et al. (2007) emphasises that more traditional approaches can be used within a RtD framework, since once initial research artefacts have been created, researchers can use more traditional design research methods to analyse them. This is the reason why chapters 4 to 6 are exploratory, while chapters 7 and 8 adopt more traditional research methods.

### **3.6.2 Mixed Methods**

This research mixes established quantitative and qualitative methods to evaluate the usability and usefulness of successive iterations of SoundTrAD, as they were developed within the overall framework of RtD.

It was felt that this combination could support a rounded insight into the suitability of SoundTrAD, and its development by using a combination of statistics and open-ended feedback. Each approach taken for the individual studies was in part decided as a result of the previous study that went before it. Specifically, a reflection on the design and resulting evaluation data of each study was used to inform the design of the study that succeeded it.

#### **Qualitative**

Qualitative approaches were employed to gain an understanding of any issues and patterns that occurred throughout the development of SoundTrAD, as well as to support the focus on a user-centred approach to the design. The research was supported by semi-structured qualitative studies (SSQS) (Blandford, 2013) that between them combined, and to an extent triangulated, rating scales, open-ended survey questions,

think-aloud procedures, observations and expert review. The user responses that were collated from the open-ended feedback were also coded for potential themes that could emerge from the collected data and subsequently help inform further iterations. This approach was based, in part, on thematic analysis (Braun & Clarke, 2006) in order to look for issues that were raised or appeared in the data a number of times. More detail of this is provided in the following section.

### **Why Thematic Coding?**

Thematic analysis was used because it is a method for identifying, analysing and reporting patterns (themes) and repeated patterns of meaning within data. Thematic analysis is an approach used to analyse qualitative data which was well-matched to the requirements for the analysis of the qualitative results of the second study. It was well-matched because it has a clearly defined, structured process to follow, as described by Braun and Clarke (2006), with clear deliverables which present the results in both visual and textual forms. It can provide the depth of analysis required when undertaking a study of a partially formed artefact such as the version of SoundTrAD as it was at the time of study two.

Thematic analysis supports the exploration of patterns across a whole dataset or a data item (an individual interview for example). A theme can belong in one item or across the entire dataset. As Braun and Clarke (2006) pointed out, a theme captures ‘something important about the data in relation to the research question, and represents some level of patterned response or meaning within the dataset’ (p.82).

Themes or patterns within data can be identified through an inductive or ‘bottom up’ approach or through a theoretical, deductive or ‘top down’ approach. The inductive approach means that identified themes are closely related to the data and may have little relation to the questions asked or the research question. The themes are not driven by the researcher’s theoretical interest in the area. It is, therefore, a way of coding the data without trying to fit it into a pre-existing coding frame or the researchers analytic pre-conceptions (Braun & Clarke, 2006). In contrast, a ‘theoretical’ thematic analysis tends to be driven by the researcher’s theoretical or analytic interest in the area.

In this thesis, a top down approach to thematic analysis was taken, in order that it could be driven by the existing analytic interest and questions of the researcher. The objective of the thematic analysis was to explore how existing topics played out across the gathered data and as a result explore other themes that could emerge and the implications these could have on the research goals, or more specifically, in this case, the implications for the development of SoundTrAD.

## **Quantitative**

To support the thesis, surveys with Likert and rating scales were used in all of the studies, apart from the first pilot study, in order to gather basic statistics to represent the usability and usefulness of SoundTrAD. The rating scales were altered between study three and study four: study three used a 9-point discrete visual analogue rating scale where anchors and a numerical value were given to the extreme ends of the scale and to the centre (Schaik & Ling, 2003). For example; 1, not at all usable, 5, neutral and 9, extremely usable. Study four refined this approach by applying semantic tags to all 7 points on the scale. This was done in order to get a more fine-grained and specific response to questions.

To analyse the quantitative data, descriptive statistics were used whereby averages, mode, mean and standard deviation were used to describe and understand the spread of the quantitative data. Alongside this, patterns were identified in the completed cue sheets. The number of events that participants identified was used to contribute, in part, to a reflection on the success of the method (studies one and three). Below is a summary of how the participants were gathered followed by descriptions of the methods used to gather and analyse data for each study.

## **Recruiting Participants for the Evaluation of SoundTrAD**

Sova and Nielsen (2003) have offered guidelines on how to recruit for usability studies. They argued that if you want to find out how well a system performs during extended use or how much iterative designs improve a system over time, then it is acceptable to reuse the same participants (Sova & Nielsen, 2003). The authors observed, however, that reusing participants for iterative tests of the same system, should be avoided if you want to study ease of learning or first exposure to a design

(Sova & Nielsen, 2003)

The researcher made sure that for each study (apart from the initial pilot) there was a combination of participants that had previously taken part in a study and those that had not. It was concluded that understanding the ease of learning of SoundTrAD was not a feature that was solely under evaluation, particularly in regards to studies one, two and three. Understanding how easy it was to learn SoundTrAD and the overall impact of the system on new users was only one of several aspects to be explored. This issue was addressed by including users with no previous experience of SoundTrAD in all of the studies. To provide insight into changes made in the most recent iteration, participants who had used previous versions of SoundTrAD were included in all but the first study.

- Study one: observations and analyses of the filled out cue sheets.
- Study two: SUS (system usability scale) (Brooke, 1996) and expert feedback (think aloud and conversation between researcher and participant), screen capture, open-ended questions, thematic analysis.
- Study three: 9-point discrete visual analogue scale survey, SUS, screen capture and open-ended questions were explored for points of interest and frequency of issues and themes.
- Study four: 7-point rating scale with semantic anchors, SUS and open-ended questions explored for points of interest and frequency of issues and themes.

### **3.6.3 The Thesis Outline and Development of SoundTrAD**

The following overviews the structure of the remainder of the thesis and how this relates to the development of SoundTrAD.

- Chapter 4: Pilot Study one. Details the first development and evaluation of a cue sheet as a technique and tool to support the designer in analysing and initially mapping out a scenario for events as made up of user actions, interface objects and resulting feedback events. This was done in order to begin to explore interface layout and the relationship between events.

- Chapter 5: Documents further refinements and developments to both the methodical steps of SoundTrAD and to the cue sheet. The chapter also accounts the very early development of a timeline and its role in SoundTrAD as a means to support a time-based representation of events and the relationship between them. Additionally, the chapter details the principles behind sound design suggestions using ideas from soundtrack composition in order to consider how the sounds will work together in the final auditory interface.
- Chapter 6: Study two. Describes the evaluation of the developments that were accounted in chapter 5. Expert evaluation and think-aloud procedures were used in order to get user-centred and expert feedback. Thematic analysis was used to devise a set of themes representative of design implications for SoundTrAD.
- Chapter 7: Study three. Discusses how SoundTrAD was refined in terms of event classifications and interface layout. The chapter reviews the development and evaluation of the cue sheet and the timeline as tools to support SoundTrAD. Additionally, it accounts the incorporation of a database of sound ideas to support the mapping of events to sound. It also presents ideas for an interactive timeline in order to support the re-ordering of events and the potential to work with different use-cases, interface interactions and layouts.
- Chapter 8: Study four. Describes a final version of SoundTrAD that is evaluated for usability, comprehension, enjoyability, usefulness and further potential.
- Chapter 9: Discussion of outcomes, contributions and future work.

#### **Introduction to Chapter 4**

The following chapter describes study number one, which involved the creation and evaluation of an early prototype of a cue sheet as a technique to be utilised as part of SoundTrAD.

The chapter describes how the study explored a means by which the cue sheet could support the designer in the requirements gathering and the conceptual stages

of AD development. This involved further drilling down into the use of scenarios for creating ADs and their subsequent, potential role within SoundTrAD.



## Chapter 4

# Study One: Scenarios And The Cue Sheet

Chapter 3 described the research that helped formulate an overall method structure for SoundTrAD incorporating stages taken from interface design: requirements gathering, conceptual design, detailed design and evaluation stages. The chapter gave insight into how steps can reside within these larger stages that draw on parallels between AD design and soundtrack composition. These parallels include the following:

- Steps that support the requirements gathering stage from an analysis of the scenario/story for characters, objects and actions.
- Steps that can support the conceptual design stage by enabling a reflection on the layout of the events in the scenario/story and a sketching of ideas.
- Steps that can support the detailed design stage by facilitating the mapping of events to sounds.
- Steps to support the evaluation of the AD being created as part of an iterative design approach.

These parallels in the different stages of soundtrack composition and AD design combine to form a conceptual blend which forms the cohesive structure of the SoundTrAD method. Figure 3.3 in chapter 3 can be referenced to see the candidate

blended space that was produced as a result of exploring the parallels between the two disciplines.

In the current chapter we will present a refinement and fleshing out of the approach of the previous chapter, and its evaluation. The current chapter will variously explore: the steps for using scenarios in the design process; an approach to action and object-based task analysis; layout of events; and suitable sound mappings.

Questions will be addressed about how a given scenario should be presented and laid out for use within SoundTrAD. For example, how can a designer be led toward thinking about relationships between a user's tasks, the context, the different events within the scenario and other requirements. How can the designer be led to consider the user context and the other sounds in the scene that could have impact on the design of the AD?

To address these issues, ideas will be explored around the use of a cue sheet as a specific technique and tool within SoundTrAD. It will be argued that a cue sheet can support the laying out of a scenario and any relationships between events, paralleling ways that a composer will spot a scene. This technique focusses on an analysis of the action and objects in the scene. It will be argued that the proposed technique for capturing the events in a scenario is independent of any particular technology. For example, the cue sheet can be realised using pen and paper. When referring in this thesis to tools, this will refer to technology-based implementations of particular methods or techniques, in this case a computer-based implementation of an interactive cue sheet.

As mentioned, the research was framed with an RtD methodology and informed by ideas from conceptual blending. Accordingly, the study described in this chapter, study one, iteratively explored the cue sheet as an artefact and as a suitable technique for use within SoundTrAD. This involved going back to the literature to clarify ideas and develop ideas around the structure and format of the cue sheet. This chapter ends by detailing an exploratory user study of utilising cue sheets (an early stage version of which was used in this study as a technique for identifying, categorising and ordering events).

## 4.1 Requirements Gathering

The first part of the proposed SoundTrAD method; requirements gathering, needs to provide the means for a designer to analyse a broad range of scenarios involving someone using audio to interact with a piece of technology; in other words using an AD. As mentioned in chapter 3, the scenario needed to be analysed to understand the nature of the users, their context, their tasks (the actions and objects involved in these) and any requirements regarding the audio representation of the events. However, there was an issue regarding how the scenario best be incorporated for use within SoundTrAD.

The following section details the literature review that was undertaken at this stage of the research in order to explore how to suitably incorporate scenarios into the SoundTrAD method.

### Working with Scenarios

A scenario is one way to represent a design problem. A narrative that, when documented, contains a beginning, middle and an end, a series of events, a cast of characters, actions, objects and a setting. However, when considering human-computer interaction, then it is important to consider that events may happen in different orders than that described in the original scenario and actions might have different outcomes. It is important to understand the different ways a scenario can be acted out and the impact this can have on the design of a system whose function is in part to model such scenarios.

The development and analysis of story and narrative to inspire sound design for the creation of ADs is not new. It was proposed by Hug (2009) that when designing the sound for interactive commodities ('computationally enhanced artefacts of everyday use') (Hug & Misdariis, 2011, p.23), creating stories about the user and their interaction with the artefact in question can be beneficial for creating user-centred designs. Hug noted how the narrative qualities of sound, as used in film to give meaning to protagonists, objects and processes within film, can influence the sound design for such commodities. To explore this, Hug developed an approach based on a participatory design process that utilised narrative, and was made up of four

significant methodological stages:

1. Analyse fictional narratives and the use of sound in film and games based around what the sound is communicating. Devise a list of meta-topics derived from qualitative measures for understanding and communicating sound choices. Base the meta-topics on descriptions of the sounds and design approach used to create it; labels, keywords, and descriptions of the relationships between actions and sounds. Apply the devised meta-topics to create narratives for the application to, and sonification of, everyday physical artefacts.
2. Formulate scenarios involving the artefact utilising the previously gathered list of meta-topics.
3. Develop prototypes from the concept, realising and communicating them practically through a performance.
4. Interpret the results based on the experience of the theatrical performance or of the user/participant's own interaction with the physical artefact.

In relation to designing sound for the interface and relating it to written film scenes, Pirhonen et al. (2006) proposed the use of a 'Syntagma' where the context of use is considered as well as the task for which the computer is used. They called this a 'rich use case scenario';

*'In order to become a Syntagma a use-scenario has to be, just as Carroll expresses, 'stories about people and their activities'. However, it also needs to be easily understood and enable a designer's identification with the people it is talking about. In that sense, the approach adopted by a scriptwriter of fiction films would be applicable.'* (Pirhonen et al., 2006, p.136)

Pirhonen et al. (2006) proposed a method for designing non-speech audio. The first three steps, that specifically addressed how to create a scenario, are outlined below. The last steps are not mentioned here because they focus on methods to map the audio using a workshop-type approach and this is not relevant to the argument at this point. Issues relating to the mapping of requirements to sound will be discussed at a later stage in the thesis in chapter 5.

The steps included:

1. Preparing a task description about the use and functions of the applications.
2. Developing a user-description, based on a vision of a plausible user.
3. Writing a short story in which the interaction between the character and the application plays a central role, taking into account that ‘the perspective is that of the character’ and that ‘there are many other things in addition to the application in his/her life and mind’.
4. Leaving blanks or pauses for the audio effects (the sounds to be designed).

### **Documenting the Scenario**

Scenarios can be represented utilising various forms and techniques, from written narratives, storyboards, videos or scripted prototypes, which often are developed using simple sketching tools such as paper and coloured post-it notes (Go & Carroll, 2004). Go and Carroll developed a means to write a scenario in a table-based format that they termed a ‘day-in-the-life scenario’ with ‘context information’ (p.125). This technique involved the marking out of the user tasks, the time of each task, details of what the task was, the location of the task and any artefacts involved. The task, its time, context and details are marked on one row of the table meaning that as a result, each line begins with the account of a new task or action.

Benyon and Macaulay (2002) argued for a systematic way to categorise and write out scenarios in order that any design decisions are traceable. In their studies they developed a way of writing out scenarios that include the following break down, in set order: ‘scenario type’, its rationale and a PACT analysis, whereby the **p**eople, **a**ctivities, **c**ontext and **t**echnologies involved are identified and summarised. After this, the story of a user and their interaction is written, followed by a set of end notes.

Diaper and Stanton (2004) referred to an ‘interaction script’ where each line of a written set of tasks becomes a ‘single main agent performing one main action’ which in turn affects other agents or objects. For example, the user does something and then the system does something in response. Important to this however, is

once again, the dividing up of the tasks/events onto separate lines in order that the scenario documentation remain systematic and clear.

#### **4.1.1 Task Analysis**

In relation to the scenario documentation is the means by which the scenario is analysed and how the scenario layout supports this analysis. A good task example describes a complete job and not just a list of simple things the system should do. Importantly, a task analysis forces the designer to consider how interface features will work together (Peters & McAdams, 2007).

This task analysis ties in with the previous conceptual design stage of interface development where the interface and its various components are considered as a whole (Peres et al., 2008). It is important at this point in the design to relate the identified tasks/events/actions in order that a coherent design is produced and thought given to the interface, its layout and the experience the user may have with interacting with it, as a result of this.

In general, approaches to task analysis and mapping may be top-down (start from the overall user goal and subdivide the steps involved) or bottom up (start from example actions and organise into an appropriate hierarchy) (Diaper & Stanton, 2004). Arguably, what is interesting and perhaps a challenge, is a means to a task analysis that can support both a top-down and a bottom-up approach in order to facilitate an iterative design process. The design decisions can then be revisited and task and event layout re-ordered in relation to the potentially changing goals of the user.

#### **Extending the Task Analysis**

Within the context of HCI, in addition to identifying the tasks and mapping them out, Benyon (2010) pointed out that further analysis can be performed in order to identify a ‘user-object’ model for which any interface objects that the user interacts with are also systematically accounted for. Benyon argued that the aim of the object/action analysis is to comprehend the objects and actions in a domain, which arguably is also another supporting argument for how important the context (domain) is for design. This also justifies considering the context of the event in regards

to the user actions and objects involved. Benyon went on to point out that that there is no definitive right or wrong answer and that the ‘object/action analysis is just another way of exploring the design space’ (p.94).

## 4.2 Developing SoundTrAD: Scenarios and the Cue Sheet

Section 4.1 has shown that being able to represent scenarios in a way that supports a designer’s ability to reason about its events, tasks, objects and actions can be of significant help in creating interfaces. These requirements closely parallel the way in which a soundtrack composer needs to be able to layout a scene and reason about its characters, actions, objects, and events.

### **Example: The Artist Scenario**

Chapter 3 presented the scenario of the Artist in their studio and applied the method stages and steps of SoundTrAD (see section 3.4). A candidate blend was discussed between soundtrack composition and interface design and, as a result of this process, it was proposed that having a clear scenario narrative could support the designer in considering event arrangement within the display. Specifically, that this could help the designer/user of soundTrAD in considering sounds that could be suitable given the layout of events within the scenario. It was concluded that the potential non-linearity of the user-actions and events within the scenario need to be considered. That transitions between the different events is important and so too is the context in the scenario and that the method stages and steps need to support the designer in iterating their design and auditioning the sound choices.

Documented next is a fuller use-case for the Artist scenario. This takes into account how the scenario can be represented in a way that supports a designer’s ability to reason about the events, objects and actions that exist in the scenario.

Also taken into account is how the designer can think about the user’s (a hypothetical user of a display that SoundTrAD can be used to create) context and the impact this could have on a user-centred design approach and the subsequent auditory interface that is produced.

The Design Problem: *An artist wants to monitor live hits to her website whilst painting. Specifically, she would like to know how many people are viewing it at any one time and how long they stay (so when they leave). She cannot watch a visual monitor of this and would also like to leave the live monitoring on whilst working and/or have it polled when she interacts with the monitoring system.*

A Use Case Scenario: *It is a Thursday morning and Sarah, a 37-year old artist, is painting in her studio, which she shares with one other artist. The radio is playing music quietly in the background. Sarah turns the monitoring system on and knows this is successful due to the short sound this makes. She goes back to painting on her canvas. Whilst doing so, she hears a sound that indicates someone has logged onto her sight, this is followed by another sound that indicates a second person has logged on. After a short wait she hears a sound that indicates that the first person that logged on has logged off. She goes over to her computer and turns the monitoring system off.*

### **The Cue Sheet**

Borrowing ideas from soundtrack composition resulted in an appropriated and adapted idea of a cue sheet as a technique to support the laying out of events from a scenario. This included the laying out of information about the user, their context (as made up of additional events and sounds), their tasks/actions and objects involved, any feedback events related to this, and the relationship between these events.

The next section goes on to describe what a cue sheet is, why soundtrack composers use them and how it was proposed it could help support SoundTrAD. This includes information on how the specific form of the cue sheet to be used in SoundTrAD was designed. Following this, the chapter goes on to describe the initial pilot evaluation of using the cue sheet within SoundTrAD.

The following section details the literature review that was undertaken at this stage of the research in order to fully understand what a cue sheet is and its potential as a technique within SoundTrAD.



## What is a Cue Sheet?

A cue sheet is a tool that is often used in soundtrack composition due to the fact that it provides a means for a composer to spot a scene and mark out places for sound (“cues”) within a given scene. The cues are marked out in a time-based format and the composer can also make notes to help with any initial ideas relating to the sounds to be used. The cue sheet encourages composers to think about any actions within the scene, associated objects and artefacts, their length and the sounds that these actions might make. It also supports the composer in identifying any emotions and moods and any ideas relating to the audio based on the given genre of the story they are working with.<sup>1</sup>

On a cue sheet, time is marked along the vertical axis, where as the horizontal axis is used to provide columns in which the audio can be categorised into different tracks by traditionally assigning them as one of dialogue, music or sound effects (‘D-M-E’s). These form the higher level categories into which the sound can be classified and subsequently easily shared amongst the post-production team, in order to facilitate the final mix.

Sonnenschein (2001) refers to a design stage in composing a soundtrack that uses the ‘1st-draft of a sound map’. This is arguably a rough sketch of a traditional cue sheet because, like a traditional cue sheet, the sound map is made up of two axes; vertical for time and horizontal for sound elements. However, unlike a more traditional cue sheet, and for this first draft, Sonnenschein (2001) recommends that the horizontal axis be headed initially in a more subjective way than the traditional headers of the dialogue, music and effects (D-M-Es). These traditional higher-level categories should be given more importance in later drafts of the cue sheet/sound map and that early versions should explore the subjectivity of sound design categorisation. In other words to let the designer use their own terms and words to describe the audio categories at the initial stages of using the cue sheet/sound map.

This exemplifies how important it is that this process of identifying places for sounds is iterative, and how subjective the process is. However, it also highlights how important the structure of the cue sheet is when it comes to organising ideas. Alongside how the final broad categories of music, sound effects (SFX) and dialogue

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<sup>1</sup><http://www.filmscoremonthly.com/features/skelton.asp> (accessed 4/7/16)

are central to organising cues and, importantly, communicating and sharing final ideas for sound across different members of a design team.

### **Why a Cue Sheet?**

At this point in the research, it had been identified that the concept of a cue sheet from soundtrack composition could be used to inspire a technique that can support an AD designer in spotting and mapping out their scenario in a way that is similar to how composers might spot a scene. That it could support the designer in identifying actions, objects and sounds that belong to the scenario. It may also then start to serve as a technique to support thinking about sound in ways based on soundtrack composition. For example, it could support the designer in laying out key events in the scenario and documenting notes and descriptions of these events that could influence initial ideas for sound design.

Additionally, it is also argued that the cue sheet parallels the approaches to scenario layout and task analysis proposed by Benyon and Macaulay (2002) and Go and Carroll (2004), where tasks are mapped out systematically (see section 4.1). The cue sheet equally facilitates the identification of objects and artefacts that are involved in the interactions and the impact these have on subsequent sound design choices.

### **The Cue Sheet Layout**

The following accounts the first design iteration of the cue sheet that was developed for use in SoundTrAD. It should be noted that this design was inspired by the principle of a cue sheet and by Sonnenschein's sound maps (Sonnenschein, 2001), in that it supports the designer in mapping out and describing events as time-based phenomena.

The first-cut version of the cue sheet to be used in SoundTrAD took the form of a printed table on A4 paper, made up of 8 columns and 5 rows per page. This was the number of rows that could comfortably sit on one A4 page and so was not representative of the number of events that it was felt adequate to document a scenario; this, in theory, is limitless. Time was represented on the vertical axis and rows for entering information from the scenario, laid out on the horizontal axis.

The cue sheet also had initial categories in which to identify the type of audio involved in the feedback event, the categories comprising Music, SFX or Speech. However, it also provided the chance to describe the sound or sound-producing object and action in more detail. This was recommended by Sonnenschein (2001). Figure 4.1 illustrates the layout of the cue sheet developed for this early stage version of SoundTrAD.

The column headers were based on things that composers look out for when spotting a scene (actions and objects) and like a traditional cue sheet there was space for notes. However, the columns were also adapted to fit the context of interaction design. For example, the note column was headed ‘attributes and descriptions’ and provided guiding text to help support the designer in taking notes that could benefit the design, such as describing the quantity or size of the object, the location in which the action takes place and any triggers that these actions may cause. There were also columns for describing the cause of the sound, ideas for what the sound could be and the type of sound. In summary, it was intended that these column headers could support the designer in spotting their scenario by looking out for actors, locations, actions and objects that are part of the scenario. Additionally, the cue sheet was intended to support the designer in initialising ideas for sounds based on this structure. The columns are listed below and beside each header/requirement (in brackets) is a short description of the purpose of the requirement.

TIME and PLACE _____ CHARACTERS/ACTORS/USERS _____								
Actions	Objects	Attributes and descriptions. <i>What do you know about the action or object? For example, Does the action or object have a size, quantity or a type? Is there a location in which the action or object happen/exist in? Does the action trigger another action or event?</i>	Do you associate sound with this? (Y/N)	Cause of sound	What the sound may be	Length of sound	Type of sound	Music (M) Speech (S) Sound Effects (SFX)

Figure 4.1: Cue sheet used during pilot study one. NB. There is a misspelled word in column 3; ‘their’ instead of ‘there’. This was an error that was present during the study.

- Title line: Time/place and character(s) involved (context and users)

- Column 1: Actions (tasks upon the interface, other tasks that cause sound within the scenario (aside from interface))
- Column 2: Objects (details of the things being interacted with, be they interface or real-world objects)
- Column 3: Attributes and Descriptions (*what do you know about the action or object? For example, does the object have a size, quantity or type? Is there a location in which action or object happen/exist in? Does the action trigger another action or event?* (descriptions and transitions and state relationships between the different events))
- Column 4: Do you associate a sound with this (Y/N).
- Column 5: Cause of sound (what triggered the sound?).
- Column 6: What the sound may be (details of feedback event).
- Column 7: Length of sound (length of feedback event).
- Column 8: Type of sound (categorisation feedback event).
- Column 9: Category: Music, Speech, Sound effects (further categorisation of feedback event).

**NB:** For the final study the category entitled ‘Cause of sound’ and ‘what the sound may be’, were separated into two categories (as opposed to the trial version of the study where it was one). Additionally, type of sound and category were separated from belonging to one category in the trial study to making up two categories in the final study. Finally, length was added as a category for the full study. For the reporting of the findings from the study, the outcome of the first two trial participants have also been included. It was felt they produced results similar to those of the participants in the full study.

### **An Example of Completing the Cue Sheet: The Artist Scenario**

Represented in figure 4.2 is an example of a completed cue sheet for the Artist scenario. This demonstrates one particular way of filling it in. Naturally, the entries

shown are subjective, but they provide an example of the mapping out of all events in the scenario, a view of the context of the Artist and suggestions for what sounds could be used to represent the different events.

TIME and PLACE <u>Thurs Morn, Studio</u>		CHARACTERS/ACTORS/USERS <u>Sarah, 37yrs, Artist</u>						
Actions	Objects	Attributes and descriptions. What do you know about the action or object? For example, Does the action or object have a size, quantity or a type? Is their a location in which the action or object happen/exist in? Does the action trigger another action or event?	Do you associate sound with this? (Y/N)	Cause of sound	What the sound may be	Length of sound	Type of sound	Music (M) Speech (S) Sound Effects (SFX)
	Radio	its on constant	Y	Broadcast	news, music live sports?	constant	Music, speech mixture	M, S, SFX
Painting	Brush, Paint Canvas	In studio, Physical objects	Y.	Brush moving on Canvas		continuous until turns on mon. system	everyday, soft, background	SFX
Turn on mon. system	Computer, button, Switch	In studio, on-screen or physical switch	Y.	Turning on	'on' sound. Positive, short	short	Musical, high pitched	M.
Painting	Brush, paint, canvas	in studio physical objects	Y.	Brush on canvas		continuous until she turns monitor off	everyday, soft, background	SFX
Someone logging on	website, internet	not in studio, virtual	Y.	logging on	short, informative	short	not too annoying	SFX
Someone logging on	website, internet	not in studio, virtual	Y.	logging on	short, informative	short	different from the last?	SFX
Someone logging off	website internet	not in studio virtual	Y.	logging off	short, informative, 'opposite' to last sound?	short	short, like the last one, slightly different	SFX
Turn off system	Computer, button, Switch	in studio, on-screen or physical switch	Y.	Turning off	off sound, negative, short	short	musical high-pitched.	M.

Figure 4.2: Example of a filled out cue sheet using the Artist scenario.

### 4.3 Evaluating SoundTrAD and the Cue Sheet

The iterative process of evaluating successive versions of SoundTrAD was started at this stage of the research with a user study. The aim of the evaluation was to gather insight into the usability and feasibility of SoundTrAD in this early form. Specifically, this involved recruiting participants for a general reflection on 2 example written scenarios as well as examining how well the cue sheet supported a means for the designer/participant to consider the user, the tasks they are undertaking and how events in the user's context could influence any sound ideas for the AD they are designing. The detail of what was being explored in this early version of SoundTrAD and gathered through the study, is outlined below.

1. Scenarios: layout and detail.
  - The level of detail needed for a written scenario, its construction and layout in order to support a successful task analysis (i.e how much support is needed to be able to identify the sonification events amidst the story).
2. Requirements Gathering: ability of the cue sheet to support SoundTrAD.
  - The mapping out of events through identification of user-actions/tasks, the objects involved, their attributes and any feedback events.
  - The comprehension of the relationship between the events.
  - The exploration of the user's context and how the mapping out and identification of all events in the scenario can influence the design of the AD.
3. Sound Mapping: gathering ideas for future use.
  - Ideas for future mappings and a database of sounds, including insight into the documented sound suggestions.
  - Document the choices made for action-object-to sound pairing; the qualitative terms and words used to describe the sounds and the classifications in order to inform the detailed design stage further.

### **Creating Scenarios for SoundTrAD**

Two scenarios were designed using an approach based on steps 1-3 from Pirhonen et al. (2006), as described above and also employing ideas from the descriptive and qualitative measures for gathering user-focussed sound design ideas from Hug (2009), as referenced above. The intention was for the scenarios to support the following objectives:

- To represent the benefits of using sound in the interface.
- To offer designers new to the process, a simple demonstration of some significant uses of ADs.
- To be kept simple to avoid confusion and enable designers to focus on use of the technique without being overburdened by detail.

The scenarios were also written on paper, inspired by the prototyping techniques suggested by Go and Carroll (2004).

The first scenario involved a student interacting with an MP3 player without a screen (inspired by the design problem presented in Frauenberger et al. (2007)) and using sound to move through a play list whilst walking. There were 2 interface events and corresponding sounds that could be identified and designed for. There were several other actions, objects and sounds present in the scenario including walking, traffic and music from the student's iPod.

The second scenario involved a professor marking a thesis in his office as a primary task but using email in the background and being informed about activities in the email application, such as when emails he had sent had been read and when new emails had been received and from whom. There were two interface events and corresponding sounds in the scenario that can be designed for. There were also other actions, objects and sounds presented with the scenario including the sound from a busy campus, the action and sound produced from walking, opening a window and turning on the computer. This scenario was inspired by the office scenarios used in the studies by McGregor, Crerar, Benyon, and Leplâtre (2006); McGregor, Leplâtre, Turner, and Flint (2010) and Coleman et al. (2008) and their developments of 'ear-witness accounts' of office sounds as being important to the design of AD's in this context. This, therefore, exemplified a scenario where context is important in the design of the auditory interface.

Written below are the two scenarios. Beside each one the PACT breakdown (people, activities, context, technology) is presented, based on the mentioned approach by Benyon and Macaulay (2002).

Within each piece of text, any feedback events relating to the auditory display to be designed, have been highlighted. It should be noted that participants did not see the PACT analysis or the highlighted text. They are presented and marked here in order to illustrate the potential analysis the scenario could have been subjected to and as a result, serve as points of reference and comparison for the findings of the study.

**1. Scenario number 1 (supporting users of ubiquitous and mobile technology)**

Figure 4.3 presents the first scenario.

Technology	This scenario describes a character using an MP3 player that does not have a screen. There is a joystick and 3 buttons on the device but all other communication from the device is audio based.)
People (user) Context Activities	John is a 33-year-old mature student who likes to use his iPod when walking outside. On this rainy Thursday morning, the walk took him through a busy street whereby, despite wearing in-ear headphones and listening to music, he was able to hear the sounds of the traffic going past. During his walk of 25 minutes he placed his iPod in his pocket and decided to listen to a new play list, comprising 12 songs. He started to listen to a song but decided to change from track number one in his play list to track number 6. Whilst walking he reached into his pocket and pushed the joystick on the device gently to the right and soon <b>heard the sound</b> that indicated that the track had now changed from track number 1. He then <b>heard the sound</b> that indicated that he had reached track six, upon which he let go of the joystick, which returned to a neutral position. He then crossed the street to enter the university

Figure 4.3: Scenario 1 for pilot study 1

**2. Scenario number 2 (supporting users who are busy and cannot continuously focus on the screen)**

Figure 4.4 presents the second scenario.

Technology	his scenario describes a character using a new email system that lets the user know when an email they sent has been opened by the recipient. The system also allows the user to know when an email has been received and, specifically, who from.
People (user) Context Activities	George is a 63-year-old professor of psychology who, whilst acting as external examiner, has the task of reading a Ph.D. thesis. On this warm Monday morning he enters his office and walks straight to the window to let some air in. He opens the window onto the busy campus below. He sits down in his chair and turns his desktop computer on and launches the email application. He does not check the email; instead he opens the thesis on his desk and begins to read. After turning 3 pages he <b>hears the sound</b> that indicates that the email he sent to his colleague has been opened, followed immediately by <b>the sound</b> that indicated that his wife had just sent him an email.

Figure 4.4: Scenario 2 for pilot study 1



## **Participant Demographics**

Seven participants took part in the pilot study, with the first two being run largely to test the experimental design, but as the results they produced were usable it was decided to count them in with the rest of the study.

Participants were from mixed backgrounds in relation to the level of experience they had with music composition and interface design. The aim of recruiting participants with varying levels of experience was to begin to identify possible categories of users for SoundTrAD. Even though it had been identified that SoundTrAD is to be used ultimately by novice AD designers, there was still a question of whether more expert users could benefit from it as well. Participants were invited individually by email to take part.

## **Tasks, Apparatus and Procedure**

The two scenarios that were presented aimed to represent two example applications of where an AD could be useful. The idea was to present the participants with scenarios that had details of the user, their context and their activities; some of which related to the auditory display to be produced and some of which, did not.

Participants were not told that they were designing an auditory display, specifically, but instead were asked to map out both scenarios using the cue sheet. The intention was to see if they could identify the events that needing sonifying for the display as well as map out and subsequently consider other noises that could affect their design choices. However, it was hoped that this would be supported through the process of filling out the cue sheet from left to right and from top to bottom and as a result identifying all events with respect to time. The idea then was that the events that related to the display being designed for, the sonification events could, in theory, be abstracted from the larger mapped out scenario, but still have been designed taking into account the other activities and events in the scenario. The participants were given a written account of the rules to explain this (see rules section below for an explanation of this).

The study took place in a teaching room at Queen Mary University of London. Participants were presented with written instructions and an example scenario with a corresponding, pre-completed cue sheet. These can be seen in Appendix A, figures

A.1 and A.2. Participants were told that they could ask questions and/or for help at any point and that they could be as creative with their responses as they liked. The voices of the participants were recorded whilst completing the cue sheets in order to capture their feedback and verbal comments during and after the study.

When they felt ready, they were given a typed and printed document containing the two different scenarios. The participants were asked to read through the scenarios and mark out the cue sheet categories from left to right. They were allowed to use as many sheets as needed and there was no constraint on the time allowed to do so. It was intentional that the amount of information the participants received regarding the purpose of the study remain minimal. This was in order to explore the intuitiveness of the approach and level of instruction needed.

## **Rules**

In order to explore the relationship between events, participants had to follow rules in order to create a time-based layout of the actions, objects, attributes and sounds in the scenarios and map them out systematically. The rules they had to follow in doing this are described below:

- Complete boxes from left to right only (cannot go backward). If a previously visited or passed column to the left is relevant then start a new line (so that actions (tasks/triggers) are always the first thing on a new line (Go & Carroll, 2004)).
- Every column does not need to be filled in and cells can be skipped.

## **4.4 Findings**

The findings below are drawn from the filled out cue sheets and verbal responses captured during the study and from a brief feedback session after the study was completed. An example of a filled out cue sheet can be seen in Appendix A, section A.2. It should be noted that due to space, not all of the seven participants' completed cue sheets are included. The example of a cue sheet in the appendix provides a good representation of how they were completed.

The number of identified events are presented in table 4.1 followed by a brief analysis and reflection on this. This is followed by descriptions of how the cue sheets were completed, again followed by analysis and reflection. The participant responses that relate to the method stages are then illustrated. Finally, there is an overview of the sound mapping and early ideas for suitable sounds at this stage.

### **The filled out Cue Sheets**

Table 4.1 outlines the number of AD events that were identified by each participant for each scenario.

Participant	Sc.1	Sc.2
1	2	4
2	3	4
3	1	2
4	2	2
5	1	1 (2)
6	5	2
7	1	1

Table 4.1: Identified auditory display events for scenarios 1 and 2.

### ***Analysis/Reflection***

Table 4.1 indicates the difference in responses between participants. However, despite the range in the number of interface events that were identified, all participants still managed to identify the events that were marked out in the example figures 4.3 and 4.4. Therefore, it is worth reflecting on how the participants interpreted and mapped out the events in order to get to this.

### ***Notes on the completed cue sheets***

Outlined below is a summary of how the cue sheets were filled out and how, despite the range of responses relating to the number of events identified and descriptions of these, there is still an argument that the cue sheet supported an approach towards similar design outcomes between the participants whilst supporting creativity as reflected in the range of responses. More detail on how the cue sheets were completed in support for this argument is given below.

- Scenario 1:

- P1 identified the same two display sounds that are highlighted in the example.
  - P2 identified the same two display events from the example but also added a ‘digital, sound effect’ to the action of John pushing the joystick on his iPod.
  - P3 did not design sounds for the display as such. Instead he or she identified the action of ‘changing track with an ‘abrupt shift in music’. She combined the 2 sonification events into one.
  - P4 identified the same two display sounds that are highlighted in the example. However, he also added an extra event underneath each one (as marked out on the cue sheet) that related to the mechanical ‘click’ sound that would also have been produced from the protagonist changing tracks using the joystick. So as a result, the two feedback events were split into four and could, in fact, represent a successful use of the cue sheet as intended.
  - P5 identified one auditory display event and like P3 combined the two events into one (‘changing track’ - ‘music, digital sound’) but did identify and combine the fact that there will be music from the iPod affecting the auditory display feedback sound.
  - P6 identified the same two display sounds that are highlighted in the example but also assigned extra sounds to the sound of the joystick on the iPod. She then assigned two speech tracks to the auditory display events before adding in two extra auditory display events that related to the actions of releasing the joystick (‘distinctive unique set of beep or ring’) and it returning to a neutral position (‘a dinger reassuring that disengaged’).
  - P7 identified one auditory display event and like P3 and P5 combined the two display events into one. Like P5, she also identified the fact that the iPod would also be playing music along side the AD.
- Scenario 2:
    - P1 identified the two auditory display events and mapped them as ‘branded

digital noise’. However, she also mapped the act of turning on the computer and the launching of the email application to branded digital noise as well. This reflects that previous knowledge and expectation could greatly affect the design choices.

- P2 also added in two extra events adding a ‘sound effect’ to the ‘PC firing up’ and a ‘music/speech’ sound of a ‘letter falling into a letter box’ for the act of launching the email application. The participant then added a ‘bell’ sound to represent that the email he sent to his colleague had been opened and a ‘woman’s voice saying: “hello”’ to represent that his wife had sent him an email.
- P3 identified the two events and assigned a ‘short soft bell’ to both events. However, she observed that each one would have to be ‘slightly different’ in pitch to distinguish between them.
- P4 identified the two events adding a ‘short sparkle’ to indicate email being read and ‘two positive chords on vibraphone’ to indicate email from his wife. However, he also added in a digital sound to represent the launching of the email application. Additionally, the participant broke this up into the mechanical whirring of the hard drive and the ‘rising triumphant’ sound that the application would make once launched.
- P5 identified the two events but only assigned one sound (a ‘beep’) to the last action of ‘looking at email list’ in order to represent George seeing the email from his wife. Interestingly, this reflects the fact that different interpretations can be made. For example, you could argue that the act of seeing an email should not relate to the sound it made when it arrived, but none-the-less the participant still assigned a sound to the email arriving.
- P6 identified the two events assigning a ‘ding or trilling’ to represent the email being read and a digital speech sound that is ‘distinct to the person’ to represent that his wife had sent him an email.
- P7 identified and marked out one event on the cue sheet that could arguably represent both the fact that an email had been read and that one had arrived. For example, when it came to describing what the sound

could be and its type, the participant wrote that the ‘audio is triggered by the email’ and that ‘I imagine you could personalise [...] whatever you want’.

### ***Analysis/Reflection***

For each scenario the participants did manage to identify the events that were intended to be added to the display. It is possible that these could have been affected by the context, user and other sounds that were present in the scenario. However, there is no direct evidence of this apart from P4 who, directly above documenting the interface event, accounted for and mapped out the other sounds (‘mechanical whirs’) that were simultaneously present in the scenario. Additionally, there is evidence of context awareness from P3, P5 and P7 who identified that the iPod would already have sounds aside from the display. However, there was no direct question to ask the participants how they felt the context affected the design choices and so this is speculative.

Arguably, there is evidence of creativity among the responses from the participants. They used subjective, qualitative words to describe the sounds and suggested appropriate sounds for use in the scenarios

In relation to the identification of events to be sonified, these were certainly heavily influenced by previous experience. For example, participant one put ‘branded digital noise’ when designing the display which indicates a prior expectation.

#### **4.4.1 Method Stages**

Written below are comments which provided some insight into how well the participants understood what they had to do and the resulting events that were identified.

#### **Requirements Gathering: Scenarios, Actions and Objects**

- *P3: “Do I have to read it all, or read and fill, read and fill?”*
- *P4: “First part involved getting used to the process and deciding how detailed or not detailed you want to be with the text. For example, every time you see something with an action do you comment on it or not?”*

- P6: *“Is it the sound you associate with each action or object?”*

### **Conceptual Design: Event layout and Early Sound ideas**

- P6: *“The bit about not going backwards; you don’t know how far to read, where to break it down. One line at a time-if you want this then break up the sentences into how you want people to read it.”*
- 3 people were confused by the column entitled ‘what the sound may be’
- 5 people questioned what was meant by sound effects
  - P6: *“Sound effects was difficult. I put it a lot because not music, not speech, but sound effects to me means someone has created the sound. But actually, a kettle being boiled is a real sound and it is not an effect, not speech and its not music”.*
  - P1: *“ It is difficult because there just is not the vocabulary to describe sound”*
  - P7: *“Can I describe the sound here? It goes [participant sings]‘beep boop’, can I just write that?”*

### ***Analysis/Reflection***

There was a limited number of participants in this initial study, but it is possible to get early insight into the extent to which the idea of considering the users of the ADs, their context and other actions, objects and sounds included in the scenario, affected the auditory interface events that were identified and how well the participants understood the function of the cue sheet.

### **Detailed Design: Event to Sound Mappings**

Tables A.1 and A.2 in Appendix A document the responses from the study. This is broken up into the events that have been identified (column 1), the cause (column 2), a response to ‘what the sound may be’ (column 3), type of sound (column 4) and category (column 5). The sound design choices reflect the range of responses

and scope for diversity in description. They demonstrate the potential for developments to the classifications and explanations that may need to be integrated into SoundTrAD.

The question of how the sounds can be categorised for future implementations still remained. Therefore, it was important to explore further how the cue sheet can be used successfully to analyse and map out the events within a scenario in order that a mapping to suitable sounds becomes integral to SoundTrAD. It was also important that the sound categories supported creativity whilst still providing structure and help towards a more objective understanding.

### **An Emerging Theme**

Interestingly, an important theme emerged that could affect further design considerations for the cue sheet and its role within SoundTrAD; that of creativity versus restriction. This will be termed (T1) in this thesis. For example, some participants preferred to be given examples of a filled out cue sheet and some did not, due to the pressure or limitations they felt this could give them in relation to their own designs:

P2 *“yeah, I think that’s one thing I found really difficult I found myself referring back to yours a bit. in a way I wonder whether you should give any example categories because you end up [...] referring back to them”.*

P5 *“I would rather not have one [an example], is that OK because I would get stressed”.*

It was suggested by one participant that he felt creativity was supported: P4: *“I figured it was an individual thing. I think that’s what is nice about what you have; people can bring things to it. Because I work in assistive technology it triggers something in me that someone from say a music background wouldn’t get. People coming from different backgrounds will see different things”.*

#### **4.4.2 A Summary of the Findings**

- The cue sheet is not really usable as a real-world analytical technique. Participants felt the cue sheet to be complicated, confusing and too open-ended, as reflected in the comments above;



- AD events can be abstracted separately.
- It is worth considering how the cue sheet supports integration of design stages;
- interesting and creative ideas for sound design have emerged from participant responses;
- there was variability between how participants identified the events, but many events were identified correctly;
- there was some evidence of creativity, but also evidence of a tendency for participants to use their own past experience to provide ideas for design, which again might in turn be seen as evidence of their limited experience in the audio domain;
- interesting issues have begun to arise such as the trade off between creativity and support, identified here as theme number one (T1);
- it is possible as researchers to glean information from the participants about how to present scenarios more clearly.

### **Design Implications for SoundTrAD and the Cue Sheet**

- Requirements Gathering Stage: scenarios and object, action analysis.
  - A written representation of the scenario that provides more guidance about how it can be broken down into different events.
  - Less focus on mapping out the ‘other’ events that exist in the scenario, in such a prescribed way.
- Conceptual Design Stage: event layout and arrangement.
  - Less restriction on how the cue sheet should be filled out with the aim of making it easier to map out the relationship between different events.
  - Supporting designers in considering both the choice of audio representation of individual events and the consequences of those choices for the AD when events occur in parallel or in quick succession to one another.

- Enable designers to iterate their process and go back and forth between the task of mapping out events. Specifically, support different approaches to analysing the scenario and mapping. For example, as P3 asked is it appropriate to “*read and fill or read, fill, read fill?*”.
- Detailed Design Stage: sound and mappings.
  - Make the (audio) categories clearer.
  - Possibly provide a tool that can support a cross-reference search of any sounds that may belong in more than one category (in order that larger categories can still be utilised to support the sharing and communicating of ideas).
- Further support.
  - Add examples of a completed cue sheet that the designer can optionally reference.

#### 4.4.3 Limitations

It is fair to conclude that it would have been advantageous to provide the participants with more context concerning the aims of the study. The study revealed a question concerning the balance or trade-off that can arise between support and creativity (T1). There was a limited number of participants and they could have been asked more direct questions in relation to the aims of the study.

However, this was an early study to get insight into the feasibility of the cue sheet-based as technique to support SoundTrAD. The cue sheet and rules for filling out the categories were intended to provide a structured way to creatively identify places for sound within a given HCI scenario, however, the means to do so were seen to be complex and less intuitive than was planned.

It could have been beneficial for the participants if the study had been more prescriptive regarding the placement of the sounds in ways inspired by the study of Pirhonen et al. (2006), rather than trying to make it intuitive. However, people on the whole identified the same places for interface sounds, so they appear to have known, perhaps based on their previous experience of interfaces, where they were required.

One major limitation of the study was the failure to randomise the order in which scenarios were given to the participants. It is possible that as a result there was bias in the ways the scenarios were analysed. For example, participants had possibly undergone something of a learning process during the analysis of scenario 1, meaning that they were more familiar with the process when they came to analyse scenario 2.

#### **4.4.4 Conclusion**

This chapter has presented study one; an exploration in the use of scenarios and a cue sheet technique within SoundTrAD. The findings arguably reflect how unusual or out of the normal experience the process of auditory display design is for most people. This unfamiliarity was also found to be the case in Frauenberger et al. (2007) when they concluded that designers could not grasp the full potential of the design space available to them for the creation of auditory displays.

The findings from this study could be argued to further support the need for and potential of SoundTrAD. However, it is clear that the early stage ideas explored in this chapter need to be developed and clarified.

Whilst being careful to keep the results of this first study under critical scrutiny, it is possible to claim that above all, the findings present evidence that the cue sheet provided an organising mechanism for placing and ordering sound elements, and that it provided feedback for how to improve the evaluation process (for example by presenting scenarios better) and ideas for how SoundTrAD should be further developed.

### **Introduction to Chapter 5**

The following chapter details the next stages of the development of SoundTrAD. The chapter introduces the idea of a timeline for representing sequences of events within the SoundTrAD method. It goes on to describe how events from the early-stage version of the cue sheet can be mapped on to the timeline, as an important early step in the process of integrating different components of the SoundTrAD method and its associated tools.

## Chapter 5

# Development of SoundTrAD

Chapter 3 argued for an overarching method structure for SoundTrAD, which included stages and steps that were based on a blending and synthesis of guidelines from interface design and approaches taken by soundtrack composers.

Table 3.1 in chapter 3 shows a model of the parallels between soundtrack composition and interface design. Figure 3.3 presents the subsequent proposed method stages and steps for SoundTrAD that were proposed in that chapter. Specifically, figure 3.3 illustrates how SoundTrAD has four method stages based on interface design: requirements gathering, conceptual design, detailed design and evaluation, and supporting steps within these stages that are formed from an analysis of parallels between steps for interface design and steps for soundtrack composition. Chapter 4 described a pilot evaluation of the first stages and steps of SoundTrAD. These stages and steps involve: users working with scenarios and a cue sheet to assist both with the requirements gathering stage and the conceptual design stage of the SoundTrAD method, and users working with steps to support the layout of the events in the scenario and the interface. Chapter 4 also discussed the development of an early prototype of the cue sheet as a technique for mapping out user actions, objects and feedback events from a given scenario; an approach that was intended to support the designer in considering the hypothetical user and their context when thinking about the sound design for their auditory display.

## Reflections on the Findings from Study One

It was concluded, as a result of study one, that the cue sheet provides both an underpinning concept and a practical technique for the SoundTrAD method. As an underpinning concept, it brings to the method a means of organising sounds from soundtrack composition practice, and combines this with the ability to specify events occurring in an interactional interface, and so provides a linkage of these two areas of practice fundamental to the philosophy of the SoundTrAD approach.

The cue sheet effectively exploits two parallels between soundtrack composition and auditory interface design: 1) the need to identify places for and select appropriate sounds for presentation, and 2) the need to consider the timing and sequencing of events.

A major difference between the two disciplines, that is dealt with in later material (section 5.3), is the fact that the sequence or ordering of sounds in an AD may change according to different use cases, whereas the sequence remains the same in conventional soundtrack composition (as opposed to more recent forms of soundtrack composition in which consumers of an interactive film might alter or make decisions about the course of the scenario). This difference in the handling of event sequences is enabled through the introduction of an interactive timeline (see chapter 6).

As a practical technique, the cue sheet provides a format for use by AD designers for laying out events occurring in the interface and how these may relate to sounds used for event representations. The process of iteratively developing a form of the cue sheet, that was to be more usable, would be the subject of further RtD-based investigation. These RtD-based developments to the cue sheet can be referenced specifically, in sections 7.2.1 and 8.2.1, respectively.

A further important issue arising out of the results of study one is the need to explore how the further stages and steps of the SoundTrAD method could be better integrated.

The study showed the unsurprising variation in sound suggestions and descriptions between the participants. While variations in choices of sounds between designers using SoundTrAD are always likely, and indeed perhaps desirable, it was felt that the results gained from this initial study highlighted the need for logic, structure and finer categorisation to help with the mapping of information to sound.

Study one also highlighted the need to develop a set of principles to support sound design suggestions by users in order that the end-user of SoundTrAD (AD designer) may access the suggested candidate sounds and consider using them within their design. However, there were issues with the usability of the cue sheet and interestingly, an emerging theme around the trade-off between creativity and support (T1) was identified as an important consideration for the design of SoundTrAD at this stage.

As a result of the findings, a set of design implications and ideas for further development of SoundTrAD and for the cue sheet, specifically, were identified. These are recapped below.

### **Design implications for SoundTrAD and the Cue Sheet**

- Requirements Gathering Stage: scenarios and object, action analysis.
  - A more guided representation of the written scenario to show how it is broken down into the different events.
  - Less focus on mapping out the ‘other’ events that exist in the scenario, in such a prescribed way.
- Conceptual Design Stage: event layout and arrangement.
  - Less restriction on how the cue sheet should be filled out with the aim of making it easier to map out the relationship between different events.
  - Supporting designers in considering both the choice of audio representation of individual events and the consequences of those choices for the AD when events occur in parallel or in quick succession to one another.
  - Enable designers to iterate their process and go back and forth between the task of mapping out events. Specifically, support different approaches to analysing the scenario and mapping. For example, as P3 asked is it appropriate to *“read and fill or read, fill, read fill?”*.
- Detailed Design Stage: sound and mappings.
  - Make the (audio) categories clearer.

- Possibly provide a tool that can support a cross reference search of any sounds that may belong in more than one category (in order that larger categories can still be utilised to support the sharing and communicating of ideas).
- Further support.
  - Add examples of a completed cue sheet that the designer can optionally reference.

### **The Research at this Stage**

The following section 5.1 proposes a set of three design aims (identified below by the numbers 1-3) for the development of SoundTrAD abstracted from the design implications from study one. Section 5.1 then goes on to discuss the resulting modifications that were made to the SoundTrAD method.

Following this, the present chapter goes into more detail of the developments that were made to SoundTrAD with a focus on the literature that was reviewed and an account of how this review informed the update. These detailed developments are documented in sections 5.2, 5.3 and 5.4, respectively, and can be identified by their related number (1-3).

At this stage RtD played a big part in the research process. The work was exploratory but is reported here because it demonstrates further conceptual blending between soundtrack composition and interface design and the updates exemplify a ‘portfolio of artefacts’ (Gaver, 2012; Zimmerman et al., 2007).

## **5.1 Summary of the Aims and Subsequent Developments to SoundTrAD**

- **Number 1. Design Aim:** Requirements Gathering Stage.
  - To carry out further exploration into existing approaches to the use of scenarios in the design of auditory interfaces.
  - To develop an understanding of how the information that needs to be represented through audio can relate to the user and their context within

a given scenario.

- In turn, to consider how the sounds that are being produced within a given scenario, integrate and relate to the hypothetical user of the auditory display, that SoundTrAD is being used to design, and their context.
- Further develop the method steps to support this.

- **Further Developments:**

- A guided means to identify the requirements of the information that was being sonified and the relationship between this and the hypothetical user in a systematic manner was developed, alongside a set of supporting method steps. See sections 5.2 and 5.2.1 for detail of this update and proposed method steps.

- **Number 2. Design Aim:** Conceptual Design Stage.

- To explore the representation of events that have been identified from an analysis of the hypothetical user, their actions and the information requirements, as time-based phenomenon.
- To explore the use of a timeline within SoundTrAD in order to represent the fact that events may evolve over time and change order within the scenario as a result of user interaction.
- In relation to the above, to further consider that a key characteristic of sound is that it is rendered over time and that, as in soundtrack composition, it is important to provide a mechanism for auditioning sounds in different orders to evaluate their effectiveness at different times when potentially they might occur in the scenario.

- **Further Developments:**

- The development of a timeline to represent the events and their potential to change order within a given scenario.
- The presentation of the initial sound design ideas in text form based on a selection of mappings. Specifically, mappings based on research into the way sounds are treated in a soundtrack for various dramatic and narrative



functions and how these can parallel possible uses for audio within an AD. See section 5.3 for detail of this development.

- **Number 3. Design Aim:** Detailed Design Stage.
  - To explore examples of the use of sound in the soundtrack and question whether there are any parallels between the audio that is used in a soundtrack and what it could be used to represent in an AD.
  - To undertake a structured investigation into direct relationships between uses of audio in a soundtrack and uses of audio in an AD.
  - To develop a sound palette/mapping principle in order to further explore the blend between AD design and soundtrack composition.
- **Further Developments:**
  - A suggested principle of a mapping scheme/database as a result of gathered and collated suggestions on how the specific uses of audio in soundtrack composition can map to specific applications, functions and objects of the auditory interface and to any data or information parameters.
  - A proposal that this database can, in principle, be updated and populated and might be continued to be so by any future community of users.
  - The subsequent development of an initial platform or space to represent potential and proof-of-concept for a database. See sections 5.4 and 5.4.1 for details of the mappings and proof-of-concept database.

## 5.2 Number 1: Requirements Gathering

The research so far has argued that it is important to consider the user's story when creating an auditory display: argued to be useful to adopting a user-centred approach to auditory interface design. For example, the research addressed ideas around mapping out scenarios involving hypothetical users interacting with everyday objects and computer interfaces with the focus on the locations and environments in which these interactions take place. The research, to date, has addressed how the sounds produced in the context (locations and environments) and audio feedback

events from the interactions, combine in a given scenario and the importance these have on the auditory interface being designed.

However, the argument was now taken a step further with the consideration of the information's story when it comes to designing auditory displays and the relationship this bears to the user. In this case, information was a term used to describe any information that needed sonifying; whether that was the representation of an action upon an interface (the act of turning something on, for example), an object (the representation of an interface object such as a button, for example), information about a system state (such as the consistent monitoring of an activity, for example) or the representation of a specific quantifiable data point or dataset (a specific number or set of numbers such as a temperature reading, for example).

Therefore, under further examination was how the hypothetical user and the information (detail of what is being sonified) could relate to one another within a given scenario.

## **Background and Previous Work**

Stephen Barrass's often cited TaDa method for auditory interface design and sonification utilised an approach to AD design that drew on stories and narrative in order to consider the user and the data and, specifically, the relationship between the two (Barrass, 1996a). For a detailed account of TaDa the reader is referred back to chapter 2, section 2.2.6. However, to summarise, the method involved supporting the designer with steps for situation description, user task analysis and information and data structure analysis. TaDa then supported the designer in mapping the outcomes from the user and information analysis to sound, through the use of 'Earbenders'; a database of stories about everyday activities and their related sounds.

Similarly, Back and Des argued that the design of audio for 'computational environments' could benefit from the imposition of a narrative structure. Specifically, they observed that an artefact could help communicate its functionality by 'telling the user its own story and by using the right story for any given state or activity' (Back & Des, 1996, p.1). Back and Des pointed out that the challenge, therefore, was for the sound designer to combine the different sound elements to tell the right story about the artefact, stating that 'what makes a story work is not so much the

choice of particular events but rather the shape and ordering of these particular events' (Back & Des, 1996, p.2).

In relation to this, Back and Des discussed the problems of designing interactive and non-linear narratives and observed that transition points are key to making the events cohesive and supporting the bridging from one small narrative section to another. However, they noted that some overall protocol must be established for manipulating the linkage and that in music, this linking may mean attention to key, tempo, voice and volume.

There has also been research into the role that narrative can play in information visualisation in order to support the communication of scientific data to wide audiences and create novel approaches to design (Gerson & Page, 2001; Segal & Heer, 2010; Ma, Liao, Frazier, Hauser, & Kostis, 2012).

As Ma et al. (2012) argued, 'framing data as narrative' by breaking it up into settings, plots and characters, makes it more 'interesting and memorable' (p.13). The setting, they argued, is all of the background information that a viewer needs to know in order to contextualise and comprehend the visualisation (Ma et al., 2012, p.12).

### **5.2.1 The Supporting Method Steps for SoundTrAD**

As was the case for study one, the designer still needed to analyse a given scenario to get an insight into the requirements for the AD. Specifically, for study one this involved looking for accounts of how, when and why the user interacts with the interface, in the form of actions upon the interface (as triggers for sound events), their context and other audio events within the scene.

To support a similar analysis with this iteration, SoundTrAD still supported the designer in identifying, analysing and mapping the scenario for the requirements listed below. The first five requirements concern the user and their interaction. These requirements included an identification of when the hypothetical end user of the interface interacts with it, where this takes place (the context), how they interact with the information in the interface (what task or action) and how they are listening (passive or active) to the sonified information. The following seven requirements in the list below supported the information analysis and so, as a result, guided the

designer in obtaining the story of the information that needed to be sonified in order to provide it with its own narrative strand within the scenario.

Specifically, these requirements came from a need to help the end user/designer gather requirements for their design. Study one provided open text boxes for the end user/designer, however, at this stage, the options for the designer were prescribed. This helped cater for an exploration into the level of support to give the end-user and draw into question the level of trade-off between creativity and support. Something that study one had identified as a significant theme for the design of SoundTrAD (T1).

## **Requirements**

### 1. Users (tasks):

- When does the user interact with the interface?
- Where does this occur/where are they?

### 2. User and Interface:

- How do they interact with the interface?
- How are the users listening?
- What are they doing and how does this in turn trigger and affect the information that needs to be sonified?

### 3. Information:

- What type of information is it (feedback event, status or data point)?
- What properties or characteristics does it (the feedback event, status or data point) have?
- What physical attribute does the audio need to represent?
- How does the information behave, and can this be rated?
- Is it (the feedback event, status, data point) discrete or continuous?
- Does it do anything to trigger other information or user stories?

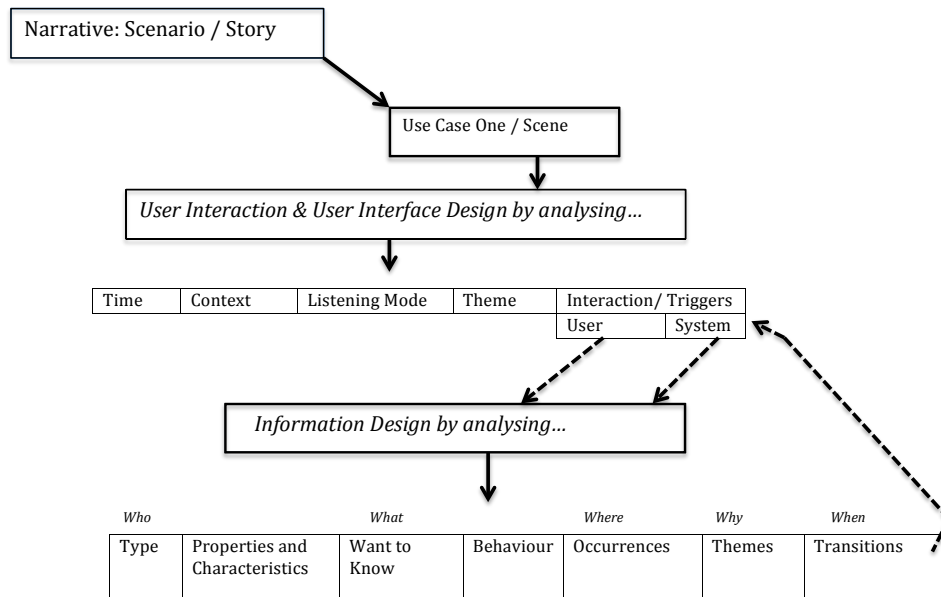


Figure 5.1: The method steps for analysing requirements for both the user of the auditory display and the information that needs to be represented through sound.

Figure 5.1 outlines these method steps for SoundTrAD and how they could support the designer in considering the relationship between the user and the information story. Specifically, it illustrates how a designer was supported in relating the information design to any user or system actions by mapping out transitions between the different events.

### 5.3 Number 2: Conceptual Design Stage

SoundTrAD needed to support the designer/end-user in understanding the relationship between the events within the scenario. This understanding was supported through a text-based representation of sound suggestions that were gathered as a result of analysing the user and information stories.

The events and subsequent sound suggestion that were identified as a result of the requirements gathering stage, could be laid out in chronological order on a timeline. However, importantly, the principle that these events could change order was also represented through the text. For example, the text presented sound design suggestions for each event and between each of these events was a description of a suitable transition sound that help support the integrating of one event to another,

Time→

Event 1		Event 2		Event 3		Etc
Sound Suggestion:		Sound Suggestion:		Sound Suggestion:		
{Type of Sound, Musical Treatment, Parameters, Digital Audio Effects}		{Type of Sound, Musical Treatment, Parameters, Digital Audio Effects}		{Type of Sound, Musical Treatment, Parameters, Digital Audio Effects}		
Transitions		Transitions				

Figure 5.2: The timeline.

despite the order the events could occur in. The next chapter describes how the timeline was implemented and so gives specific detail and examples of this particular design feature. However, in this chapter figure 5.2 illustrates this design principle.

Detail of the relationships between the requirements and audio that were explored at this stage are outlined below. This involved a further investigation into the ‘blend’ between soundtrack and auditory display. Specifically, an investigation into any similarities between what sound can represent when used in a soundtrack and what it can represent when used in an auditory interface.

## 5.4 Number 3: Detailed Design Stage

The arguments that exist in support of how the practice of film soundtrack composition can inform the design of audio for ‘computational environments’ have been documented in chapter 2, section 2.2.7. However, despite these theoretical ideas, there still remained a question of how to realise or apply these ideas given a real design problem. For example, despite the argument from Bishop and Sonnenschein (2012) that sound designers for on-line learning environments could benefit from film industry practices, such as utilising the way people listen to sounds, considering sound from the start of the design process, and identifying those storytelling elements that can be amplified by sound such as ‘objects, actions, environments, emotions and physical and dramatic tensions’ (Sonnenschein, 2001), it was not necessarily apparent (or rather there is no widely recognised repository) of how these could help the designer apply sound to a computational on-line learning environment. Specifically, there was no insight into how, or indeed whether, these gathered storytelling elements can map to specific sound suggestions such as a type of sound to

use, or what compositional technique one could use to represent an action, character or object, emotion or transition, for example.

Therefore, the aim of this part of the research was to explore examples of similar functions of audio when used in both a soundtrack and an AD. To see if what it needs to represent within the scenario can be classified according to the things composers have to look out for and take into account when spotting a scene; the plot and its characters, their actions or behaviours, objects, locations, moods or transition points between narrative events (Sonnenschein, 2001). The aim was to explore whether, as a result of these classifications, the sounds could map to the requirements (narratives) gathered about the user and the information at this point, and as a result, question whether a sound design suggestion to suit the requirement could be provided.

To support this further, the sounds were categorised, not only, according to the function they serve within a soundtrack and what they could be used to represent within the scenario, but how they could be identified and placed into music-based categories.

This was a direct follow-on from study one, which had begun to explore how the participant's sound description could be further categorised into music, speech or SFX. Therefore, at this point, the audio was broken down further into categories from musical constructs such as melodic patterns, harmony and arrangement, to low-level musical parameters such as pitch, rhythm, or timbres. This was done in order to explore whether the information analyses (see section 5.2.1) could be mapped into these lower level musical elements.

Itemised below in list form are ideas taken from the literature concerning the functions of sound within a soundtrack. These are identified according to what composers listen out for and need the audio to 'amplify' (Bishop & Sonnenschein, 2012). Within this list the ideas are categorised into musical genres/types and the specific techniques or compositional treatment applied.

## **Representing Plot, Objects, Actions, Environments, Moods and Transitions.**

### ***Genre/Type***

- Important to the success of film sound is the structure of the sound, not only

on micro-levels but as an overall. ‘In addition to communicating general mood or character representation and development, a well-crafted musical score can clarify or even establish a sense of order by presenting a clearly perceived formal structure’ (Lipscomb & Tolchinsky, 2005, p.401).

- ‘By establishing patterns in the use of **music, sound effects, and silences** and then manipulating these established patterns within the temporal flow, a film can be made to feel subjectively like it is speeding up or slowing down’ (Lipscomb & Tolchinsky, 2005, p.5).
- Non-diegetic sounds (sounds that do not belong on the on-screen story-world) such as **underscore, narration and ambience** are linear and not interrupted with the scene, as such they effectively serve as a ‘smoothing element for visual edits whilst also promoting continuity’ (Beauchamp, 2005, p.23).
- ‘**Underscore** can represent a character’s inner world’ (Beauchamp, 2005, p.45).
- ‘**Underscore** can be ambient or thematic and often used to provide a sonic background that can elicit an emotional response’ (Beauchamp, 2005, p.45).
- ‘**Ambience** contributes to continuity and defines physical boundaries’ (Beauchamp, 2005, p.68).
- ‘**Underscore** is often used as a substitute for ambience, providing a background that promotes an emotional response’ (Beauchamp, 2005, p.45).
- ‘**Music** can readily convey pace’ (Lipscomb & Tolchinsky, 2005, p.402)
- **SFX** can ‘represent a character’s outer world’ (Beauchamp, 2005, p.45).
- ‘**Music effects and effects scoring** is where chords of varying volume and dissonance [are] used to exaggerate actions’ (Beauchamp, 2005, p.46).
- Doubling of **underscore and Foley** can give a pitch and harmony to off on-screen events (Beauchamp, 2005)
- **Ambience: non-synchronous effects** can be used to establish a background in which action takes place (Beauchamp, 2005)
- **SFX** can be used to establish time period, locations and character development.



- ‘Characters are often developed through associated props such as a type-writer for a journalist, for example’ (Beauchamp, 2005, p.63).
- Sound effects: Divided into units including **hard effects**: narrative sounds linked to on-screen objects or actions. Further broken down to editorial effects:
  - a) **literal sounds** added to on-screen events
  - b) **design effects**: objects or events requiring non-literal treatment (Beauchamp, 2005)
- **Foley**: Some design considerations when deciding which objects to represent (‘cover’) through sound (Beauchamp, 2005):
  - Is the sound object made from organic or synthetic material?
  - How does the sound object move or interact in the environment?
  - Is the sound object narrative (character or story point development) or ambient?
  - Is the sound object intended to support realism or subjectivity?

## Musical Component/ Compositional Technique

### *Harmony*

- Harmony and instrumentation can be used for characterization (Beauchamp, 2005)
- **The minor 7th** is expressive of painful feelings (Arning & Gordon, 2006).
- **The diminished 5th** was seen as a sinister chord (Arning & Gordon, 2006).
- In Hollywood films **the fifth** is used to signify the other, the alien, the sinister and the threatening (Arning & Gordon, 2006).
- Communication of meaning: Sadness is conveyed by **slow pace, falling contour, low pitch and minor mode** and happiness is conveyed by **fast tempo, rising tempo, high pitch and major mode** (A. Cohen, 1998).

### *Instrumentation*

- **Acoustic instruments** are associated with organic environments (Beauchamp, 2005).
- **Synthetic instruments** are associated with mechanical or technological environments (Beauchamp, 2005).

### *Melody*

- **Pitch shifting** can alter age, size and gender of a character (Beauchamp, 2005).
- The pairing of a musical theme to a specific character is called a **leitmotif**. Once a motif is established, we can anticipate or experience a character on or off screen simply by hearing that character's motif (Beauchamp, 2005)
- Music as memory cue: a **leitmotif**, in the absence of visual cues, will cause people to imagine the individual or theme (A. Cohen, 1998).
- **Melodic themes** can follow up and down motion of on-screen actions or objects (isomorphism) (Beauchamp, 2005)
- **Ascending and descending lines** can promote direction (Beauchamp, 2005)
- A **leitmotif** is a 'theme, or other coherent musical idea, clearly defined so as to retain its identity if modified on subsequent appearances, whose purpose is to represent or symbolize a person, object, place, idea, state of mind, supernatural force or any other ingredient in a dramatic work' (Whittall, 2001).

### *Arrangement*

- **Loud sounds** tend to mark the beginning of a group, and a **lengthened sound or interval between sounds**, the end (Collins, 2009)

### *Rhythm*

- **Rhythmic elements** propel the action forward and cease when resolution is required (Beauchamp, 2005, p.22).
- The **tempo of a sync** can effect the sense of real time (Beauchamp, 2005).
- **Regular rhythm** good for peripheral and background (Cooley, 1998, p.2).

- **Non-regular rhythm** good for foreground sounds (Cooley, 1998, p.2).

#### **Treatment/Effect**

- **EQ** plays an important part in establishing depth
- **Panning** can establish the width (of scene).
- **Frequencies** can create a height perspective (Beauchamp, 2005)
- **Higher frequencies** represent something is closer and demands more attention (Cooley, 1998)
- **Distortion** can be associated with the largest imagery, fuzziest images and ‘dirtiest’ images. (Collins, 2009)
- **Reverb** is often associated with larger and older imagery (Collins, 2009, p.4).
- **Delay** was associated with futuristic imagery and space, as was phasing and flanging, though to a lesser extent. These sounds were also associated with hard-edged shapes, and metallic coloured shapes (Collins, 2009, p.4).
- An **increase in the height of the attack-decay-sustain-release (ADSR)** envelope is associated with unpleasant feelings, while **fast attacks** are associated with power (Collins, 2009).

#### **5.4.1 Toward a Database of Sound ideas**

The figures below present further categorisation of the list above to include suggested parallel functions between the use of audio in a soundtrack and the use of audio given a hypothetical use-case scenario of someone using sound to represent information. These figures are separated according to the spotting element (the thing a soundtrack composer might listen out for). For each figure, the first column labelled function is split into two columns. The first column lists functions in a soundtrack and the 2nd column lists suggested functions in an AD. Columns 3-6 are broken down to represent music and audio categories, which are as follows: column 3; motifs, types and melody, column 4; length, key, arrangement, instrumentation, timbre and harmony, column 5; audio parameter such as pitch, rhythm, frequency or volume and column 6; audio effect such as equalisation (EQ), distortion or reverberation.

It should be noted that only the first column (function) is fully populated with suggested parallels between functions in a soundtrack and functions in an AD. However, this demonstrates the principle of the database, its layout, and its potential to be updated. See figures 5.3, 5.4, 5.5, 5.6, 5.7 and 5.8.

***Character (data point)***

FUNCTION		MUSIC /AUDIO			EFFECTS
In a Soundtrack	Suggestions for function within an AD	Motifs, types, melody	Length, key, arr., instrumentation, timbre, harmony .	Pitch, rhythm, freq., tempo, vol.	Digital effects
Represent a character's inner world	User doesn't see visual or explicit representation of what data is portraying	Underscore, Music			
Represent a character's outer-world	When user sees visual representation of data along side sound	SFX, Everyday			
Establish/develop a character feature	When first get exposed to a characteristic / data feature	Sound of associated prop (hard effect)			
Establish Character	When first get exposed to a character / data point	Motif			
Anticipate or experience a character on or off screen	Good for unseen characters, widening perceived interaction space / data space	Hearing that character's motif			
Age, size and gender of character	Representing these characteristics about the data or information			Pitch Shifting	
Characterization	Est. character / data feature		Harmony and Instrumentation		

Figure 5.3: Database representing characters.

***Action (behaviours and user or system actions)***

FUNCTION		MUSIC /AUDIO			EFFECTS
In a Soundtrack	Suggestions for function within an AD	Motifs, types, melody	Length, key, arr., instrumentation , timbre, harmony .	Pitch, rhythm, freq., tempo, vol.	Digital effects
Exaggerate actions	Perception of User interaction and objects	Music SFX scoring whereby chords varying in vol. and dissonance are mapped to action			
Pace, speed-up, slow-down	Perception of User interaction and objects	Establish a pattern with music/SFX and then alter it	Establish a pattern with music/SFX and then alter it		
Association with physical actions	Representation of a action that has a real-world physical counterpart	SFX, hard effect, every day sound			
Propel action forward	For a sense of speed of an action			Rhythmic elements	
Literal treatment of action	When sound can be associated	Editorial effect/hard effect			
Non-literal treatment Action	When sound cannot be associated	Design effect /hard effect			
Up and down motion of onscreen action	User's sense of movement of an object		Follow movement with a musical melody (isomorphism)		
Sound can provide illusions of non-visual motion	When object is unseen but its motion still needs to be represented		Follow movement with a musical melody (isomorphism)		
Ascending and descending lines can promote direction	When object is moving in a direction		Follow movement with a musical melody (isomorphism)		

Figure 5.4: Database representing actions and behaviours.

This is an early layout of a database that is presented from a soundtrack composition point of view, in that the figures are broken up into characters, objects, actions, behaviours emotions and transitions; all narrative elements that a composer may

***Object (properties and behaviours)***

FUNCTION		MUSIC /AUDIO			EFFECTS
In a Soundtrack	Suggestions for function within an AD	Motifs, types, melody	Length, key, arr., instrumentation, timbre, harmony .	Pitch, rhythm, freq., tempo, vol.	Digital effects
Portray on-screen object/action	When user sees visual along side sound	Hard effect			
Homogenous thick, viscous texture	Represent an object but also give perception feel to interaction		String Pads		
Sensations of luxury, comfort and smoothness			String Pads		
Represent a temporal structure of an object (animated: pulsating for example)				Use temporal structures of music such as rhythm, contour, or patterning in time	
Represent larger or older entities	Tactile sense and time-based events on a timeline				Reverb
Hard-edged shapes, and metallic coloured shapes	Represent these characteristics of object but also give perception feel to interaction				Distortion / phasing and flanging
Large, fuzzy, dirty					Distortion
Proximity				Volume	
Closeness and proximity				Higher frequencies	
Height				Frequencies	
Literal treatment of object as interacted with	When sound can be associated	Editorial effect/hard effect			
Non-literal treatment Object as interacted with	When sound cannot be associated	Design effect /hard effect			
Up and down motion of onscreen objects	User's sense of movement / direction of a an object		Follow movement with a musical melody (isomorphism)		
Direction					

Figure 5.5: Database representing objects, properties and behaviours

look out for in a given scene. It should be noted that in theory, the database could be split up according to any other of the categories. It may be that the tables are broken up according to similar functions of the audio or according to musical effects, for example in order to present an alternative way to navigate them. This issue of presenting a database and its navigation is something that will be addressed later in the thesis, in study three. For now, these tables present an initial layout and proof-of-concept.

This kind of knowledge base of how sound is used in a soundtrack can play an important role in respect of SoundTrAD. As part of the database, it can potentially help guide the choice of sounds and even provide the design rationale for why sound choices were made. This might be done by including in the tables of the database meta-information about why certain sounds are good choices for particular situations, for example. However, it will always be crucial to hear the sounds in context in order that a designer could know whether the sound choice works in practice, but it is very helpful in pointing a designer, particularly someone new to AD design, in promising directions.

***Location / Environment (status/continuous)***

FUNCTION		MUSIC/AUDIO			EFFECTS
In a Soundtrack	Suggestions for function within an AD	Motifs, types, melody	Length, key, arr., instrumentation, timbre, harmony.	Pitch, rhythm, freq., tempo, vol.	Digital effects
Define physical and non-physical boundaries	When representing a place, space room through sound and interaction boundaries	Ambience			
Establish a background in which action takes place	When representing a place, space room through sound	Ambience (non-synchronous sounds)			
Organic Environ.	When representing a natural space/place		Acoustic Instrument		
Mechanical, technical Environ.	When representing a man-made or industrial space/place		Synthetic Instrumentation.		
Width of scene	Of user space but also interaction space				Panning
Cultural space outside the western sphere of reference	When representing a place, space room through sound and interaction boundaries, Possible new or foreign domain		Interval of a 5 <sup>th</sup>		
Peripheral and background	Mode of listening put object in back/peripheral. Monitoring for example			Regular rhythm	
Foreground	Mode of listening Put object upfront. Information push			Non-regular rhythm	
Music can convey the quality and size of a space	When representing a place, space room through sound and interaction boundaries				
Depth	Of user space but also interaction space				EQ

Figure 5.6: Database representing locations/environments.

## 5.5 Summary of SoundTrAD Development

This chapter has discussed how SoundTrAD was updated with further detailed steps into requirements gathering for both the hypothetical user and the information and the subsequent relationship between the two. It has examined how the use of narrative and its subsequent analysis can be used to map the requirements into a story and as a result subsequent event relationships explored and transition points between events considered. Relating to this, the chapter has then examined how sound can map to the identified events, borrowing ideas from soundtrack composition. A database of ideas has been started and whilst in its early stages, has helped to outline some principles towards its design in order that it can be developed further.

### Introduction to Chapter 6

Chapter 6 accounts developments that were made to the cue sheet and to a prototype timeline tool. The chapter describes how they were implemented at this stage in order to get feedback on some of the updates to the method steps of SoundTrAD that have been listed above.

The chapter then accounts an evaluation study of SoundTrAD. A study set to

***Transitions (between events)***

FUNCTION		MUSIC /AUDIO			EFFECTS
In a Soundtrack	Suggestions for function within an AD	Motifs, types, melody	Length, key, arr., instrumentation, timbre, harmony	Pitch, rhythm, freq., tempo, vol.	Digital effects
Continuity and smoothing	Smooth between sounds and plot. Good for the end of a sequence/process	Non-diegetic sound (ambience, underscore)			
Cue a memory	When representing a known thing or something that has been established previously	Leitmotiv; the music alone will cause people to imagine the individual or theme			
Sense of real time	Audio feedback with direct interaction on interface and with data or real time feedback on a process/activity			Tempo of audio	
Mark the beginning of a group	Start of something (task or event)			Loud sound	
Mark the end of a group	End of something (task or event)		Lengthened sounds or larger interval between sounds		
Resolution	Solving/completion of something (task or event or process)	Scale from 7 <sup>th</sup> to 8 <sup>th</sup> tone			
Represent Futuristic ideas and Space	Potential scenarios/data possibilities etc.				Distortion / phasing and flanging

Figure 5.7: Database representing transition points.

get more general feedback concerning the updates that have been addressed in this chapter, the usability of the tools, promising application areas for SoundTrAD and any resulting ideas for its further development of the method.

***Mood / Emotion***

FUNCTION		MUSIC /AUDIO			EFFECTS
In a Soundtrack	Suggestions for function within an AD	Motifs, types, melody	Length, key, arr., instrumentation, timbre, harmony.	Pitch, rhythm, freq., tempo, vol.	Digital effects
Power	Overall interaction and in relation to an event /action /characteristic			Fast attacks in the ADSR envelope	
Painful feelings	Overall interaction and in relation to an event /action /characteristic		Interval- min7th		
Sinister	Overall interaction and in relation to an event /action /characteristic		Diminished Interval: 5 <sup>th</sup>		
The other, the alien, the sinister and the threatening	A new entity / unknown process event/ object etc		Interval: 5 <sup>th</sup>		
Unpleasant feelings	Overall interaction and in relation to an event /action /characteristic			Increase in the height of ADSR envelope	
Sadness	Overall interaction and in relation to an event /action /characteristic. Better suited for processes or a series of events	Slow pace, falling contour, low pitch and minor mode	Slow pace, falling contour, low pitch and minor mode	Slow pace, falling contour, low pitch and minor mode	
Happiness	Overall interaction and in relation to an event /action /characteristic. Better suited for processes or a series of events	Fast tempo, rising tempo, high pitch and major mode	Fast tempo, rising tempo, high pitch and major mode	Fast tempo, rising tempo, high pitch and major mode	

Figure 5.8: Database representing emotions and moods.



## Chapter 6

# Study Two: Evaluating SoundTrAD

*‘Maybe stories are just data with a soul’* Brene Brown, TED Talk January 3rd 2011

Chapter 5 described developments that were made to SoundTrAD as a result of the findings from the first study. These developments included an approach to a detailed hypothetical-user task and information analysis (section 5.2) and an examination of how the information that needs to be represented through sound can be laid out and presented as a timeline of events (section 5.3). Chapter 5 then described the development of a mapping scheme based on principles of how sound is treated in a soundtrack and how this could begin to support specific tasks in the interface, and ideas for what the information needs to represent. As a result, the chapter accounted the early stage development of a database of information to sound mappings (section 5.4).

### **An Overview of the Current Chapter**

The first part of this chapter starts with details of the developments that were made to the cue sheet as a computer-based tool to support an AD designer (end-user of SoundTrAD). The chapter then details the prototyping of an interactive timeline as a tool to support the laying out of events and provide representation of the mappings of information to sound (as documented in chapter 5, summarised in section 5.1).

In section 6.1 below, this present chapter documents a specific set of mappings between information requirements and sound design suggestions that were used to exemplify the principle of the mapping scheme and early-stage database (that was demonstrated in chapter 5) during a second study evaluation of SoundTrAD.

The second part of this chapter, in section 6.2, then goes on to discuss this evaluation of SoundTrAD. Specifically, an evaluation of the updates that had been made to the steps of SoundTrAD (discussed in chapter 5) and to the cue sheet and timeline tool as a means to support these steps. This discussion also includes rationale for the mixed methods approach that was adopted during this evaluation.

The chapter then concludes by presenting ideas for further work and by identifying application domains for SoundTrAD. See section 6.3 and 6.4, respectively.

## **6.1 Cue Sheet and Timeline Development**

This section describes updates that were made to the cue sheet and the timeline as tools to support SoundTrAD.

### **Requirements Gathering and The Cue Sheet**

The rule that study one enforced of filling out the cue sheet from top to bottom, without the option to revisit responses, was discarded due to the confusion it had caused. It was still a requirement to fill out the cue sheet from left to right in order that time continued to be represented on the vertical axis and the events subsequently represented line by line. However, unlike study one, the cue sheet was now laid out to support an iterative design approach, specifically, by supporting the designer in revisiting columns and updating their choices at any point. This was supported through the development of a software version of the cue sheet that was programmed in Max/MSP. Figure 6.1 illustrates this implementation of the cue sheet.

### **Event Representation and the Timeline**

The timeline at this point in the development of SoundTrAD was there to present sound design ideas. Additionally, it helped the designer explore how the layout of the sounds related to user interactions. Specifically, it supported the designer in taking

into account how the sounds would be heard together and how they would be heard if ordered in different sequences relative to one another. It also supported the designer in paying attention to issues of masking, such as clashes of sound, unexpected effects of hearing different sounds together or close to each other; for example, by serving as an auditioning tool for the designer to prototype their display.

Each event was marked out from left to right (one after the other) to represent the order they would be heard/play out. Transition points were marked out between events. The vertical columns of the timeline represented the different musical elements that make up each event. It was planned that in future that the events could be moved around on the timeline. This event reordering was planned to enable different layouts and interaction ordering. However, at this point in the development, the events could not be moved about on the timeline and were there to represent and demonstrate this planned functionality of the timeline.

### **Implementing The Cue Sheet and Timeline**

In the previous study, the cue sheet was created on paper. The aim in this current study was to provide a link between the cue sheet and the timeline in order to support the integration of the method stages. As a result, the cue sheet and timeline were created using Max/MSP in order to implement a more fluid relationship between the two, and to enable the timeline to be updated interactively in line with the filled out cue sheet. Figures 6.1 and 6.2 depict the cue sheet and timeline at this stage in the development of SoundTrAD.

### **Mappings and the Timeline**

As mentioned, each row on the cue sheet represented one event. Individual cells within each row offers offered a space for the designer to enter information about each requirement (including the type of information, its characteristic or behaviour). To support this, each cell contained a drop-down menu with a list of options.

Figure 6.1 demonstrates the relationships between the different columns on the cue sheet and the sound suggestion that the individual requirements were mapped to. These are based on the database that had been started and can be seen in figures 5.2 to 5.7 in chapter 5.

USER INTERFACE and INTERACTION DESIGN				
1 Time	2 Context	3 Listening	4 Theme (Skin)	5 Interaction/Trigger
START	The displ...	The listen...	Theme for	The sound

INFORMATION DESIGN -----> LEFT TO RIGHT				INFORMATION BEHAVIOUR -----> LEFT TO RIGHT			
6 Classify the Information	7 FOLEY	8 Want to know?	9 Behaviour (action)	10 Occurances	11 Themes	12 Transition into next event (changes)	
What is the information that needs to be represented through audio? What identity would you give it from the following:	Properties of the object / location or character CHARACTERIZE	What do you want to the audio to communicate?	What does the information do at this point in the scenario?	IN RELATION TO	Rate the behaviour/action	Does the Information /Data Change?	What Causes this?
EVENT 1 Text one word The information c...	Industrial Indoor	How big	The enviro...	The sou...	The beha...	The sound	This is caused by L... TRANSITION / END FROM EVENT 1
EVENT 2 Text one word The information c...	Other Inner	age	The Char...	The sou...	The beha...	The Sound	This is caused by the... TRANSITION / END FROM EVENT 2

Figure 6.1: Cue sheet at this stage of the development of SoundTrAD.

TIME ----->	
	EVENT 1 EVENT 2 EVENT 3
TYPE of Sound	
MUSICAL Treatment	
PARAMETERS: Key, Harmony, Rhythm, Pitch	
DAFX: Digital Audio Effects	
TRANSITIONS	

PLAY EXAMPLE SOUND PLAY EXAMPLE SOUND PLAY EXAMPLE SOUND

Figure 6.2: Timeline (blank) at this stage of the development of SoundTrAD.

The higher-level categories under which the sound ideas were presented on the timeline are as follows:

- Type of sound;
- musical Treatment: (instrumentation, melody);
- parameters (key, harmony, rhythm, pitch);
- digital audio effects (DAFX);
- transitions.

The requirements gathered for each event regarding the type of information it needed to represent, any attributes, properties, behaviours of the information and the transitions between events; in principle, mapped to suggestions regarding the type of sound that could be used, suitable instrumentation, parameters that could be manipulated, a musical structure it could have in regards to melody and harmonies that could be used. An example mapping could be as follows:

- Requirements / Audio Suggestion
  - Requirement: Listening Mode = Passive / Audio: Ambience or peripheral sound.
  - Requirement: Type of information to represent = An Object / Audio: Hard effect.
  - Requirement: Attributes and Properties = Industrial / Audio: Synthetic instrumentation.
  - Requirement: Attribute or Characteristic to represent = Amount / Audio: Loudness (volume).
  - Requirement: Behaviour = Moving Up / Audio: Rising Melody to match this action or / steady melodic pattern to follow this action.
  - Requirement: Occurrence of event = Continuous / Audio: match to length of audio.
  - Requirement: Mood associated with event = Negative / Audio: minor key.

Table 6.1 is not meant to be comprehensive, but provides examples of possible mappings. It serves to illustrate the concept that was addressed in the last chapter, section 5.4, for mapping suggestions from soundtrack composition on to the information requirements for the auditory display being designed.

### **A Demonstrative Set of Sounds for the Study**

To provide an example of the use of this mapping principle, and for use in the study to evaluate SoundTrAD, three sounds were created. To represent the sound of changing electricity use (a requirement for the study as clarified below in section 6.3), a low electrical hum was sampled. The electrical hum was felt to represent a ‘hard effect’ and the ‘everyday sound’ of electricity. It also represented a suitable sound that could support passive listening, alongside provide properties to support the representation of an industrial and man-made object. To represent an increase in electricity usage, the pitch of the electrical hum rose and its volume increased. To represent the steady use of electricity, the pitch of the electricity stayed the same. Participants were presented with two design options, and two different sounds to use with these. If the rise in electricity was to be seen as negative, then the hum was played with a minor chord underneath, if the electrical rise was to be interpreted as positive, then the hum was played with a major chord underneath.

It should be noted that the participants did not have full control over the sounds and not every requirement was mapped. However, there was an aim to keep the number of sound choices intentionally small and so these sounds were utilised to demonstrate the potential of the approach. This is described in more detail in the following section 6.2.

## **6.2 Data Collection and Evaluation**

The evaluation of this version of SoundTrAD used both qualitative and quantitative measures in order to carry out what Blandford (2013) termed a ‘semi-structured qualitative study’ (SSQS). It was considered that the sole use of predefined quantitative measures would not be appropriate for this study because the aim was, in part, to capture people’s reactions to using SoundTrAD. Therefore, using and looking for correlations between qualitative and quantitative measures was considered appro-

priate. As mentioned, this approach was used to compliment the RtD methodology that underpinned the research.

Blandford used the term ‘SQSS’ to refer to qualitative approaches to data gathering and analysis. This, she argued, normally involves ‘interviews and observations, that have some explicit structure to them, in terms of theory or method, but are not completely structured’ (Blandford, 2013, p.2). This approach normally involves iterative coding of verbal data, alongside the analysis of other forms of data to compliment this qualitative approach to coding. Examples of combining qualitative and quantitative data could include correlating survey data with open-ended responses, or interaction data with verbal feedback, in relation to the use of an interactive system, for example Bengler and Bryan-Kinns (2013).

### **Observations and Screen Capture**

Apple Quick Time, version 10.4 was used to record the participant interaction with the screen alongside any dialogue that accompanied this from either the participant or the researcher. This was based on semi-structured think-aloud sessions between the participant and the researcher. This enabled the capturing of any dialogue between the researcher and participant as well as the audio and visual interactions of the participant as they interacted with the cue sheet and timeline.

### **Survey**

To support the SSQS, Brooke’s system usability scale (SUS) survey was also used to gather quantitative feedback on the usability of SoundTrAD (Brooke, 1996). The survey is documented in Appendix B. The SUS was chosen because it permits a single score to be calculated that represents the usability of the system under evaluation. The survey is made up of 10 Likert scale statements that the participant can respond to on a range from strongly agree to strongly disagree. As Brooke pointed out, it can be seen that the selected statements cover a variety of aspects of system usability, such as the need for support, training, and complexity, and as a result have a ‘high level of face validity for measuring usability of a system’ (Brooke, 1996, p.192).

## **Thematic Analysis**

Out of the range of approaches and variants for conducting SQSS described by Blandford (2013), thematic analysis (TA) was chosen because it was a particularly good match for this study. For a more detailed justification of this decision the reader is referred back to chapter 3, section 3.6.2.

To summarise, it is a method for reporting themes that are not explicit in a data set or related to responses to specific survey questions. It is useful for its ‘minimal’ organisation, yet the rich analysis it can provide (Braun & Clarke, 2006). According to Braun and Clarke (2006), analysis involves moving back and forward between the collected data set, the coded extracts of data under analysis, and the analysis of the data that is being produced. As a result, the data collected from the screen and audio capture from this study went through the recommended 6-phase process of coding (Braun & Clarke, 2006).

### ***6 Phases***

- Phase 1. Familiarise your self with the data, transcribe it. Search for initial themes.
- Phase 2. Generate initial codes; identify whether the term for the code is explicitly articulated by participants or inherent in what they said (semantic content or latent).
- Phase 3. Search for themes; after the data is coded, start to categorise these into themes and end this phase with a collection of candidate themes, sub-themes, and all extracts of data that have been coded in relation to them.
- Phase 4. Review and refine the themes to build a candidate ‘thematic map’.
- Phase 5: Define and name themes; organise the collated data extracts for each theme into a coherent account, with an accompanying narrative identifying the ‘story’ that each theme tells. Report how the themes fit into the broader overall ‘story’ that is being told about the data, in relation to the research question(s). It is important to ensure there is not too much overlap between themes.



- Phase 6: Produce the report; create a final map of themes and a description of how they fit in with the larger goals of the research.

The research applied, what Braun and Clarke identified as, a ‘theoretical’ approach to the thematic analysis of the data (Braun & Clarke, 2006). This meant that the data was analysed with pre-defined existing topics in mind and coded for instances that related to these topics.

The initial topics were directly derived from the original features that SoundTrAD would provide and what it could support the designer in achieving as a method and tool. Section 1.2 in chapter 1 and section 3.4 in chapter 3 can be referenced to see these aims in context, however, for clarity they are summarised below.

1. To lower the barrier to creating ADs in order to enable novice designers to engage effectively in the AD design process.
2. To support the iterative refinement of AD designs. Addressing the recognised need to evaluate as part of the design process.
3. To enable the designer (user of SoundTrAD) to complete a prototype/model of their design. Once again to support evaluation as part of the design process.
4. To support the designer in executing accountable, repeatable steps toward producing a display that communicates whatever it is that was intended to be communicated (Kramer, 1994).
5. To capture the different perspectives of AD designs such as the display’s behaviour over time. To consider the linearity of the narrative of the scenario and the fact that interactions may occur in different orders. To consider multiple timelines.
6. To enable the designer to consider suitable event to sound mapping. To think about the aesthetic in so far as how the different sounds can blend and work together. To consider each sound in relation to the other sounds presented within the scene/display while considering the impact of the audio as a whole composition (Lipscomb & Tolchinsky, 2005). To consider the auditioning of sounds as part of an iterative design process.

7. To enable the designer to document their ideas in order to support the referencing and sharing of design rationale. In relation to this, to support them in organising sounds into categories based around different ideas or cues.
8. To offer computer-based tool support for the method. Specifically, to support the designer in an iterative design process and working with sounds. Namely, the mapping of events to sounds, the auditioning of sounds and the ability to work with multiple timelines in relation to this.

The topics used in the evaluation of SoundTrAD were derived from the above list. However, they were summarised and refined into 6 overall topics in order to suit the evaluation of SoundTrAD at this stage. To clarify further, this refinement was done because it was felt that these 6 topics related to the recent updates and developments that had been made to SoundTrAD. Additionally, it was felt that matching these topics to the findings could also help answer useful questions regarding the nature of the target users for SoundTrAD and its possible application areas. These 6 topics are written below alongside a short justification of how the topic was derived and why it was being applied to the evaluation of SoundTrAD.

- Topic 1: Target users.
  - The aim was that SoundTrAD would be suitable for novice designers but questions existed as to whether more experienced designers could use it as well. Therefore, it was felt that exploring occurrences of this topic could help answer this question.
- Topic 2: Aesthetics.
  - The aim was that SoundTrAD could enable a designer to consider aesthetics in their design and due to the significant work that had gone into exploring how events can work together and subsequent mappings to audio at this stage, this was considered a suitable topic for exploration.
- Topic 3: Usability.
  - Considerable work had gone into the development of the computer-based tool to support users in applying the SoundTrAD method and so it was important to evaluate the interfaces of the tool at this stage.

- Topic 4: Enjoyability and Creativity.
  - To enable an enjoyable and creative design experience. This was considered to be a suitable topic in order to gather the end user/designer’s perspective on this, particularly in light of the updates that had been made to the tools.
- Topic 5: Iteration and integration.
  - To evaluate how effectively the stages of SoundTrAD had been integrated and whether they supported users in taking an iterative approach to design.
- Topic 6: Usefulness.
  - To identify to which types of scenarios and domains SoundTrAD could be applied. Clarity was needed regarding this in order to guide the further development of the method.

Below follows another list of topics that were also used to code the data. These topics were directly derived from the developments to SoundTrAD that had been carried out to the method steps for requirements gathering, event layout, and mapping as well as the tool developments (reported in chapter 5 and here in chapter 6, respectively).

- Developments to the steps of SoundTrAD:
  - Topic 1: Requirements gathering.
  - Topic 2: Conceptual design stage and event layout.
  - Topic 3: Detailed design stage and the mapping scheme.
- Tool implementation:
  - Topic 1: Cue sheet and developments to its layout.
  - Topic 2: Timeline and its creation in order to represent the events and sound suggestions.

The reason for choosing pre-defined topics for carrying out the coding was to specifically explore how the original aims of SoundTrAD (what it aims to support as a method and tool) related to the updates that were made to the steps and to the supporting tools, i.e. to examine to what extent these developments and updates supported the overall aims of SoundTrAD as a method and tool. Additionally, there was also an intention to look for any further themes that came from the examination of the relationship between these original topics in order to explore the design space and gain ideas for further work.

## 6.3 The Study

### Scenarios

The participants were required to analyse and map out on the cue sheet a scenario of someone using audio to monitor their home electricity use. The scenario was made up of a user action as a trigger for a continuous system event which reflected the status of the system and a user action as a trigger for the display to stop. The idea with this scenario was to begin to explore and refine the type of scenarios the method could be used for, in particular working with combinations of user actions (triggers) and process monitoring, reflected in the continuous event. The reader is referred back to chapter 2, section 2.2.2, pages 28-29, for a review of monitoring and ADs. However, to place it in context here, the scenario (which is referenced below) utilised the idea that the user turns on a monitoring system, which is then used to monitor and constantly provide feedback about electricity use. The electricity use changes state during this process and as a result, the user turns it off. This is a simple example, but represented how different types of events (user actions and continuous events) can combine and affect one another in a monitoring scenario.

Below is a model of how the scenario was made up and how the events related to one another in time.

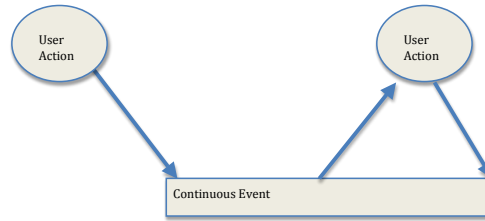


Figure 6.3: Event layout.

## Equipment

The participant used an Apple iMac with a 27-inch monitor, keyboard and mouse. Quicktime Player, version 10.4 <sup>1</sup>, was used for data recording and Max/MSP was run to present the cue sheet and timeline.

## Participants

At this point, it is fair to state that it was known that SoundTrAD was not fully developed to support all target users and that an insight from experts, was valuable to progress further at this stage. As a result, for this study, participants were individually chosen and invited (by email) to take part in the study because they had some experience of interaction design.

Nine participants were selected from Queen Mary University of London. The range of students that Queen Mary University provided with experience in media arts technology and sonification/AD research was impressive. It was felt, therefore, that a suitable cohort of participants could be selected from the University. Participants were from either the Media Arts Technology (MAT) PhD course or completing Post-Doctorates in computer science. A short questionnaire prior to the study was used to establish how much interaction design experience they had. The survey was also used to capture whether they had other experience or knowledge that would relate specifically to ADs and/or music composition. All nine, as mentioned, had interaction design experience, six out of the nine had experience with AD design and three had experience of music composition. This data is presented in table 6.2.

Recruiting nine participants was considered to be an appropriate number because, in part, SoundTrAD was still at a formative stage and not yet ready for

<sup>1</sup>[https://support.apple.com/en\\_GB/downloads/quicktime](https://support.apple.com/en_GB/downloads/quicktime) – 27/8/17.

larger scale evaluation. It was felt that nine participants would be enough to provide sufficient feedback to be able to draw out codes and themes in the TA while keeping the time required for the study and for the analysis manageable.

It was explained to the participants that the study was to support the design process by gathering measures of usability alongside user feedback; specifically, ideas, thoughts and suggestions. Participants were encouraged to ask questions and think-aloud if they felt comfortable doing so. It was fully explained that they were part of a targeted user group and that, as a result, their expert opinion was important to the iterative design process. The participants were told that it was the system under test and not them and that there were no right or wrong responses to the tasks.

## **Tasks**

The study took place in a teaching room at Queen Mary University of London. All participants took part in the study individually and were sat in front of the computer. The researcher was in the room and was monitoring the participant's screen with a screen which mirrored that of the participant. Participants were allowed to ask questions and, in general, a dialogue between the researcher and the participants was encouraged. The participants were given a print out of the following:

### ***Steps:***

1. You will be presented with a written scenario involving a person interacting with a system that uses audio to communicate its state;
2. The scenario is made up of two events;
3. You will then be presented with an on-screen cue sheet and timeline;
4. Basing your responses on the written scenario, you are required to fill out columns 2-5 of the cue sheet;
5. Basing your responses on the written scenario, you are then required to fill out columns 6-12, from left to right. This is marked 'event 1';
6. You will then be prompted to go back and fill out columns 6-12, from left to right again. This is marked 'event 2';

7. You then have the option to review the sound design suggestions that are formed and written on the time-line;
8. You then have the option to listen to an example piece of audio to illustrate how your answers informed the sound design;
9. Please ask for guidance at any point. There are no right or wrong answers!

**The scenario:** A home electricity monitor conveys 3 pieces of information. These include:

1. Amount of electricity being used in kwph;
2. Cost of electricity in pounds;
3. The amount of carbon emission.

**Use case 1:** A home-owner wants to be able to turn on the monitoring system and use audio to constantly monitor the amount of electricity being used whilst it is on. They will be engaged in other activities and monitoring the electricity as a background activity.

There are two main events in this scenario:

1. Event 1: User turns system on and the electricity use is steady and consistent for some time;
2. Event 2: The electricity being used goes over a desirable threshold. After this, the user turns the monitoring system off.

## 6.4 Findings

### Thematic Analysis

**Phase 1:** Screen captures were used to gather data from the participants. The dialogue and interactions with the cue sheet and timeline, were transcribed. Each line of dialogue or description of an action was time-coded and placed into its own row in an excel spreadsheet. These transcriptions can be seen in Appendix C.

**Phase 2:** The set of pre-defined topics were used to analyse the dataset (see section 6.2 for a list of these). The data was subject to a theory-driven analysis, in

that it was explored for where these topics ‘played out’ amongst the transcriptions. The topics were colour coded and numbered. The numbering mirrored the numbering used in section 6.2 and this can also be seen in the coding in Appendix C. For example, any passages of text relating to the overall aims of SoundTrAD were coloured blue, a method update was coloured orange and tool update, light green. Written in these colour coded cells was the relevant number associated with each topic. For example, if the text was found to be relevant to the target users then the cell was coloured blue and labelled with a number 1. It was also possible that multiple topics (colours and numbers) could be applied to the same piece of text. See Appendix C for this phase of the coding.

**Phase 3:** Once these topics were identified, the relative section of transcribed text (where the topic played out) was subject to a semantic description. The highlighted topics and text descriptions can be seen in Appendix C next to the relative section of transcribed data.

**Phase 4:** Based on these descriptions, the data was then broken into further themes and a thematic map was produced. This map physically attaches the further themes to the original topic so that they can be seen to relate, which in turn can be associated with either an aim of SoundTrAD, a tool update or a method update. This can be seen in figure 6.4. The colours and numbers relate to those used in phase 2 of the coding process. These further themes and their ‘story’ are described below in reference to phase 5.

**Phase 5: “Story”:** In order to see links between themes and further refine the map, the story of each topic (utilised in phase 2) and related theme (as anchored in phase 4) was described. This was based on the process described in phase 3 - the semantic transcriptions of the coded segments of text. This is written below and each story is illustrated with a quote or example from the transcriptions. It should be clarified that the topics derived from the aims of SoundTrAD as a method and tool will nearly always relate to the updates that were made to the tools and to the method stages. This, in theory, meant that the text coded for an aim of SoundTrAD should relate to whether the aim was supported by a tool or a method update. As a result, any theme that was found to relate solely to an update to the method or tool, for example, revealed that it might have been an update that did not support an



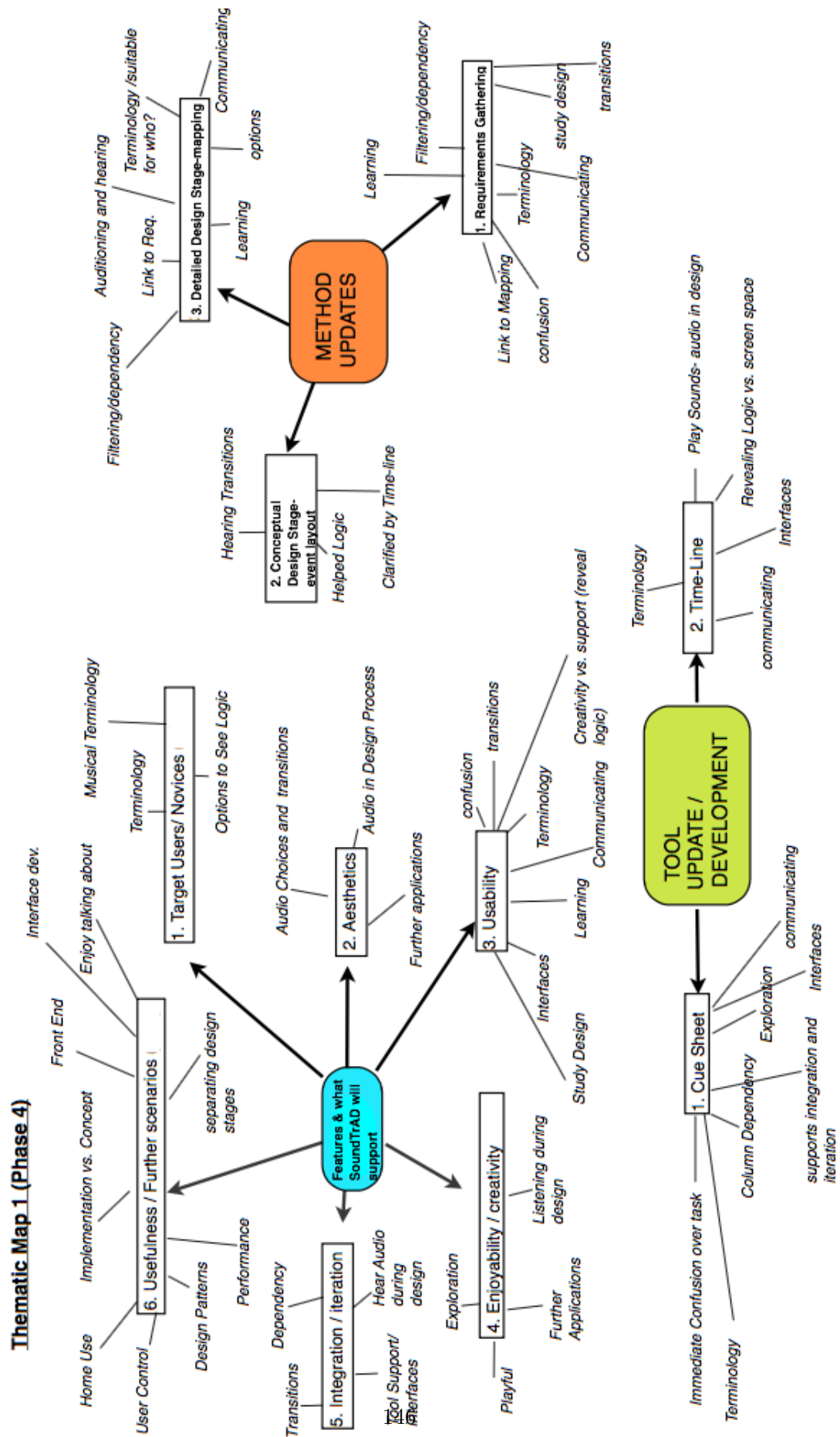


Figure 6.4: Phase 4. Thematic map 1.

original aim of SoundTrAD. Similarly, any theme relating just to an original aim of SoundTrAD and that did not tie in with (or can also be found as theme relating to) an update, demonstrates that potentially this aim of SoundTrAD was not addressed in an update. In order to try and organise this, the story that follows is categorised according to the aims of SoundTrAD and themes surrounding this. Within this, the story description clarifies whether the theme also related to a tool or a method update.

**Topic: The features of SoundTrAD and what it supports as a method (blue)** 1. *Target Users*, 2. *Aesthetics*, 3. *Usability*, 4. *Enjoyment and Creativity*, 5. *Integration and Iteration* and 6. *Further scenarios and applications*.

## 1. Target Users

The transcriptions were coded first for text that could relate to target users. The idea of it being suitable for novice designers was affected by the terminology and issues with the updates made to requirements gathering, which was found to be too advanced and specialist:

P8: *“what do you want the audio to communicate .. yeah, some of these words are really like sound-designy and I have heard them, but I don’t really know what they mean.”*

The musical terminology was also seen as too specialised. This related to issues around how a novice designer could understand the updates made to the mappings:

P6: *“OK , yeah, um so who is the target for this? [..]yeah, I think, er, I probably fall under that you know. I know a bit about sound but I can’t use the terminology, you know, people who are familiar with synthesising sounds and stuff, I don’t have that kind of knowledge, so er..”*

P6: *“sorry, what’s Foley?”*

The theme of audio in the design process also related to the suitability for novice designers:

P5 *“I think because I design just by listening because I am not a pro, by listening to a lot of stuff and then choosing one that I like ..I don’t really care about the categories you know.”*

Finally, there was a theme around options to see the logic behind the mappings that also related to updates to the event layout and to the timeline. Below is a quote from P6 that was captured after they spoke about the target users, as quoted above.

P6: *“So I am just thinking, like, if I’m very curious then.. about, all of these design things and harmony and stuff like that then this would be nice to have (pointing to the timeline) and I can come here and I can see how my choices map to actual sound stuff, that’s nice. But if I am not really interested in that, then do I need to look at this? What’s the advantage of having this?”*

## **2. Aesthetics**

When coding for text that related to aesthetics, it was found that themes relating to the use of audio in the design process were also apparent:

P6 *“so for example if this is, if I’m not a sound designer and I have no idea of what all of this is going to bring out what would be nice, I don’t know how this works, but if there is like a (laughs) this is a bit crazy, but some sounds and then these sounds are changing as I’m choosing different options.”*

Audio choices and transitions was an issue relating to the updates to event layout:

P7: *“and then you want to have the difference between if it has been steady or been changed, and if it has been steady you want it to be quite ambient.”*

Further applications was also a theme that related to aesthetics. For example, when talking about possible future applications, P4 spoke about separating out the sound part from the design part in order to think about the audio choices:

*“yeah, or even, um, make it more of a kind of musical kind of performance; the sound design part, but keep this system this way, I would imagine.”*

### 3. Usability

When coding for text that related to usability, several themes were identified: Terminology was found to inhibit usability, once again relating to the updates made to the requirements gathering stage:

*“OK, so the word [...] what is threshold exactly?”*

There were also issues around learning and the time needed to get used to the system. This was also related to issues around the usability of the interfaces and updates made to the tools

P8: *“ I imagine that most people would learn to use this system very quickly’..yeah if its, like laid out a little bit better then, yes.”*

Usability was also affected by issues around the event layout and related to the layout on the timeline:

P7: *“yeah, I think it would be helpful to have (looks at timeline) a summary of the event on this page.”*

Usability was also affected by the impact of the interfaces. In a few cases the initial impact of the cue sheet seemed to create confusion over the task at hand

P9: *“so my 1st reaction is oh [...] too much information, what should I do.”*

The timeline and cue sheet proved to be useful but had issues with their usability. Useful because they helped reveal logic and also helped to tie in the method stages and steps, portray transitions and anchor the method concept, but their usability affected this:

P8: *“No, I think its really; can be really really intuitive but, yeah, it needs a differnt, I don’t know if its the visual interface that needs to be different.”*

The colour coordination between events also seemed to benefit one participant. This relates to usability and could also relate to the accessibility for novice designers or how well the integration of the method steps are supported:

*“so the scenario is made up of 2 events. OK, so I can see events in pink, that’s good.”*

The study design also seemed to affect some of the comprehension of the terminology used and usability:

*“I mean it might have been useful to know at the beginning that you were mapping soundtrack things to these sort of systems.”*

The conflict between revealing logic and design rationale and whether this is or is not needed or wanted as part of the design process was acknowledged by several participants. There was also a clear acknowledgement of how this impacts screen space and ease of use:

P7: *“it is going to get quite large .. but I guess what you could do is have, you could fill in this stuff (points to timeline) and then press the button and it sort of minimises itself but it is still there so if you want to go back you can just maximise it but you can still see the suggestions at the same time.”*

Finally, an emerging theme that related to usability was how well the study communicated the concept or idea behind SoundTrAD. This could be seen to relate to the study design and the initial sense from the participants of how usable SoundTrAD is:

P6: *“so is this like, intentionally has no instructions? I’m not really sure what I am doing.”*

#### **4. Enjoyability/Creativity**

When coding for text that related to enjoyability and creativity it was found that exploration was supported and taken up by more confident participants. For example, the first thing participant 1 asked was whether they just *“play with it”*, before spending just under 2.5 minutes working through the tasks and without any dialogue with the researcher. This could also, it could be argued, relate in a positive way to the usability of the interfaces.

Once again, issues around listening as part of the design process were also apparent as a way that the design process could be more enjoyable. For example, two participants asked to hear the audio once they had finished the first event.

The participant's general enjoyment and creativity seemed to be reflected in particular regarding their closing remarks about the study. These also seemed to tie directly in with updates and future versions. For example, P2 felt that *"It is really important research I think. I'm looking forward to how it develops."* P5 *"It is really fun I am looking forward to seeing another version."* It was also felt to be fun and playful:

P1 reflected on it as *"Cool, that's really good."*

P9 *"yeah, but I like it because I think it is very playful, but useful as well. I just want it now, so I'm thinking about where else can I have it."*

Creativity, specifically, could be seen reflected when participants were filling out the cue sheet and selecting the requirements:

P8: *"I like natural its quite nice. Water is bit a cheesy [selects electricity] a little lightening?! that would be nice (laughs)."*

The users showed appreciation of context as an option for the requirements which enabled creativity:

*"I think it also depends on your first choice in context. Because I have chosen home now, it's like, yeah I would say wood, but if I would choose work it might have been something else."*

## **5. Integration and Iteration**

The theme of audio in the design process was also found when coding for integration and iteration:

P8: *"it's a nice overview, but if we are just being practical and I just want to produce something I would probably just want to see this right? (points to cue sheet) and then somehow have this background, have this sonification playing and then I can sort of [...] its almost like you've, when you have these DAWS and stuff and can maybe mute this (highlights E1*

*in the timeline) or maybe just go to this (moves to E2 on timeline) and see what the transition sounds like.”*

Participants critiqued issues regarding the requirements gathering filtering and the link to the mapping. This column dependency was found to be an issue for two participants:

*P5: “but the problem is the inter-dependency you know when you change something and you, yeah, it took me a bit to understand that, this effect.”*

It was found by participants that there was a lack of apparent logic between what was selected in the cue sheet and what got displayed in the timeline. This can be seen as a reflection on the integration of the method steps, the requirements gathering, mapping as well as the tool updates.

*P6: “So I guess my 1st impression if I’m being naively honest is.. so, my .. I couldn’t basically relate these things (pulls up cue sheet and points to timeline) with the decisions I had made in the previous ones.”*

*P7: “yeah, because it’s quite difficult to make the link actually. I mean, there must be like reasons why it does, why it sort of makes the suggestions, so it might be interesting to see the reasons.”*

However, the timeline did help clarify the function of the requirements gathering in relation to the mappings. For example, people seemed to show understanding once the timeline was illustrated during the study. This highlights the importance of iteration and integration but also the way that this is supported. Also, issues around study design were illustrated by this, in that, the relationship between the cue sheet and timeline should have been demonstrated before the participants started the tasks.

Iteration was also important to all of the participants. Every participant switched from working linearly when using the cue sheet to going back and forth between the cells and columns when choosing their responses. Participants also did this after they heard the audio or saw the time-line. For example, participants asked if they could go back and change their answers once they heard the audio that related to their responses or they were shown and explained the timeline and the relationship

it bore to the rest of the method. Once again this was related to the theme that has emerged - the importance of audio in the design process as central to user comprehension and the perceived usability of the method.

## 6. Usefulness/Other Scenarios

When coding for text that related to usefulness and further scenarios, it was found that discussing future applications was seen to be enjoyable for three of the participants. There was a suggestion for its application for performance-based scenarios from P4 and as a front-end to a set of design patterns from P6. However, it is arguable, particularly with P7 and P8, that their ideas for where it could be used are influenced by the home-electricity scenario they used for the study:

P8: *‘But it’s like I want my coffee machine, I want my alarm clock, I want my ..I want anything in the home.’*

P7: *“ovens. I am just thinking household things now [...] ahh...something, a computer that ..yup, because I have had this before where I have got quite a dodgy program that i am working with at the moment, not because it’s liked cracked or anything, but just because it’s rubbish, and it crashes and it would be really useful to know whether I need to turn it off or just need to wait.”*

P7: *“baking..., ah yes, body clock that’s a good one. When the plants need to be watered.”*

P4: *“yeah, it’s really interesting. Especially if you have, you end up with this complex map of events you are interested in sonifying. If you were to separate that from the synthesis part, the sound part [...] or even, um, make it more of a kind of musical kinda performance; the sound design part, but keep this system, this way, I would imagine.”*

Context was also related to its perceived usefulness and application contexts (as supported by the requirement that permitted the designer to select the context of use for the AD). For example: P8



*‘it feels a bit, it feels quite personal so I’m not sure if I would bring it out of the confined space - so maybe it doesn’t work for ‘work’. But yeah, it would be different at work.’*

Themes also emerged around the tool and interface development and suggestions for future work. For example, P7 felt that a designer could *“fill in this stuff (points to the timeline) and then press the button and it sort of minimises itself but its still there so if you want to go back you can just maximise it but you can still see the suggestions at the same time.”*

P4 also made comments about separating out the design part from the sound synthesis part of soundTrAD. This related the theme of aesthetics and sense that a user could have more control over the sounds to future developments.

## **Phase 6: Final Themes**

Phase 6 of TA involves making a list of the final themes, with a short explanation and implications for larger research questions. This was done by consolidating the most common recurring themes. The aims of SoundTrAD, the method updates and tool developments (and the themes that related to these) are discussed below, based on the most common themes that were identified when coding the data using this theoretical starting point.

As a result, the coding process served as a way to explore all the themes that have come from the original topics, the relationship between them, and as a result how different aspects of the tool and method updates support the different aims of SoundTrAD as a method and tool.

Three final themes were identified. The other themes that had been identified and can be seen in the original map, were then categorised under these three final themes. Figure 6.5 outlines these three main final themes and diagrammatically illustrates how the other themes relate to them. This is discussed below.

## **Explanation**

The most common themes have been labelled and are described in relation to the other themes and implications below:

**Audio in the design process (T2):** Found to be a theme when coding for aes-

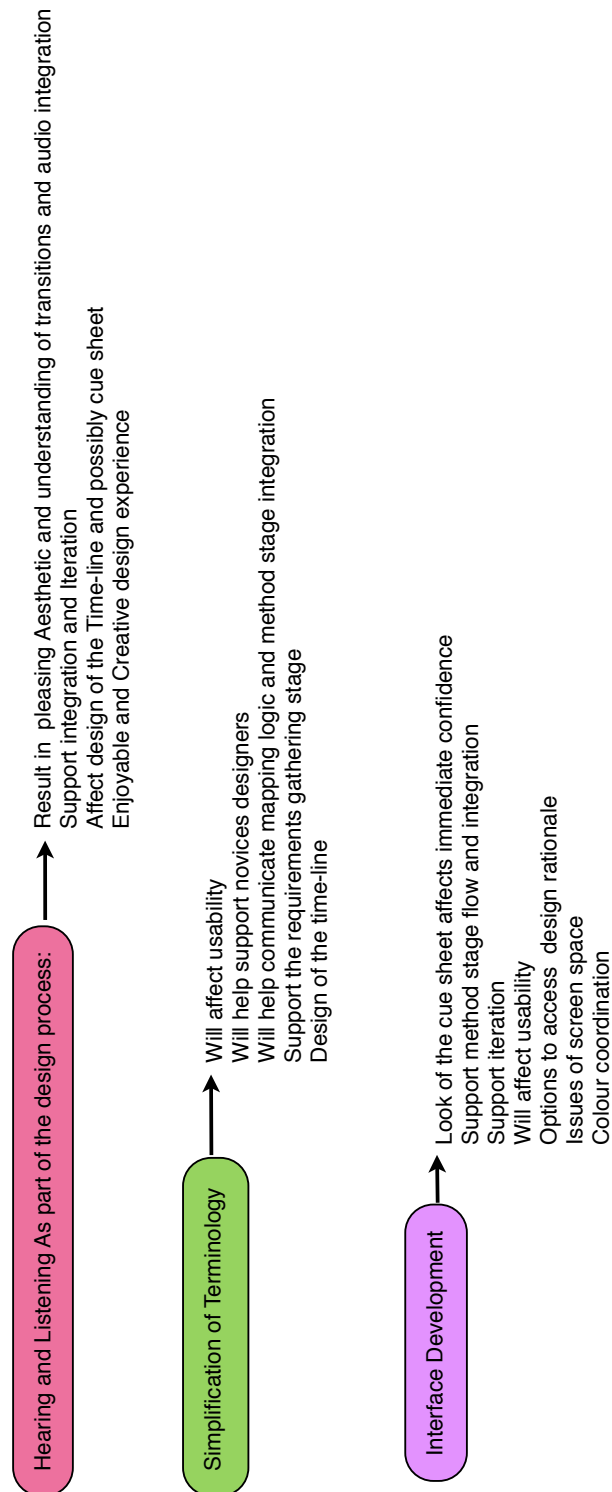


Figure 6.5: Phase 6. Final themes.

thetics, enjoyability/creativity, integration and iteration; tool development and event layout. In summary incorporating audio earlier in the design process and during the requirements gathering stage will support the designer. They will not only enjoy and find the experience more creative, but they can also relate the different stages (for example, hearing how their decisions affect the sound design suggestions). Hearing audio (specifically transitions) could also support this and in particular the comprehension of event layout and how the events relate to one another. This, therefore, has implications for the design of the cue sheet and timeline.

**Terminology (T3):** Found to be a theme when coding for target users and usability and requirements gathering and mapping. In summary, simplifying the terminology could help the target users. For example if they are novice interface designers or have no experience of audio they will find this easier. Additionally, making the terminology consistent between the stages could also support method flow and comprehensibility. For example, links between the requirements gathering and the mapping stages. This will also have implications for the design of the cue sheets and the timeline and how the sound suggestions are presented (the number of words, for example). This relates to the next major theme; interface development.

**Interface (T4):** As mentioned, considering audio in the design process and terminology will have implications for the design of the tools. Issues around the interface were found to be a theme when coding for usefulness, integration and iteration, event layout and for the cue sheet itself. There were issues around how much information the designer actually needs or wants in order to successfully carry out the design task. It was mentioned by three participants that having optional access to information and design rationale would be better and that hearing the audio in the process would be better than reading about it as feedback. Design patterns, user-control, front end, screen space, play buttons and on-screen interaction all came up as things to consider in relation to interface development.

**Reflections on T1:** Study one (in chapter 4) highlighted the difficulties arising from facilitating creativity and the trade off this had with the level of support to

give a designer. This was identified as a theme for the first study when evaluating SoundTrAD for usability and general feasibility. The issue also came up frequently during the study reported in this chapter, particularly in relation to the terminology, interface and thoughts concerning enjoyability. It was found that hearing audio would perhaps be less restrictive or ‘rigid’ than having text feedback. It was also a theme that related to requirements gathering and the suggestions and options that were available to the designer. As P6 observed, *“this is creative as you can get versus, you know, complete freedom and not knowing where to begin.”*

It is fair to argue that this will be a trade-off in any system like this, as P6 continued to observe:

*“Well I think that’s the typical issue with these designs, if I may say, kind of design frameworks or whatever. It is always like you have a trade-off between how you are restricting creativity by imposing this kind of rigid framework or should you just keep it completely open and then you lose any kind of structure - it’s very hard to trade off.”*

This is a very interesting theme and one that can be reflected on through the thesis, not only in relation to usability, but specifically alongside explorations into how the other identified themes can be used to inform the development of SoundTrAD.

## **Usability Scale**

Figure 6.6 shows the different responses to the usability scale. The scores as percentages range from 37.5 to 97.5, with a mode of 62.5 and a mean score of 62.2.

The standard deviation from the average score was high at 21.12. This could be argued to reflect the variability in usability and perhaps on the complex nature of what people perceived they were judging. For example, the interfaces to the tools and implementation of SoundTrAD versus its aims and potential, study design and comprehension of the task at hand, including issues regarding how to communicate this clearly to the participants. In particular the problem of directed support versus freedom of creativity and issues with the interface. This relates once again to method implementation and evaluating how effectively the aims of SoundTrAD have been effectively achieved.

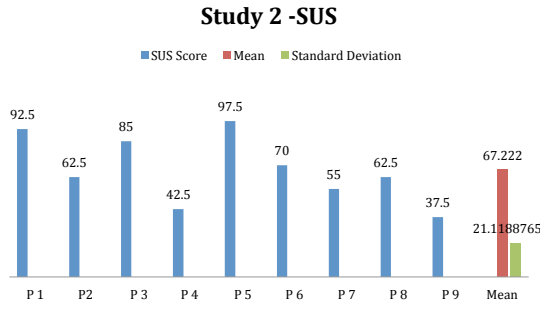


Figure 6.6: SUS usability of the system.

#### 6.4.1 Limitations

There were errors in the study design. This was very significant as it reflected on the levels of comprehension, particularly in regards to event classification in relation to the scenarios. For example, for the study, two events were identified as taking place during the scenario whereas it could have been four and this interpretation could have been clearer. This was picked up by three participants:

P7: *“there is a difference between user events and system events and so you should make that clear. I am not saying that you need to separate them but..because there is actually going to be a user event and a system event at the same time[...] When you turn it on you would just get the ambient one (event) because it wouldn’t have necessarily changed the moment you turn it on so it would be a system event saying ‘I’m steady’. It depends what your’e looking at.”*

P2: *“Can I ask, actually about the meaning? The user, talking about events; ‘user turns the system on and electricity use is steady’, I’m confused, actually I’m not sure [...] it should be the system, like, it could be an on-off switch or the electricity that I am trying to capture? but I shouldn’t ask.”*

P8: *“Electricity use goes over a desirable threshold and then the user turns the monitoring system off, so again this is 2 events.”*

### 6.4.2 Summary

This second study evaluated the updates that had been made to SoundTrAD. These updates (documented in chapter 5) included developments to the steps to support user task and information analysis, event layout and the mapping of information to sounds based on ideas from soundtrack composition. The updates also included developments to the cue sheet and a timeline as tools to support a user of SoundTrAD (documented at the start of chapter 6).

The study helped outline how well these updates and developments to SoundTrAD supported the original aims of SoundTrAD, in terms of what it will support as a method and tool. The study has also provided insight into ideas for further design and application domains that could be utilised by SoundTrAD.

It was clear from the analysis, that utilised both qualitative and some quantitative measures to explore the updates, that further development to SoundTrAD could help answer questions concerning the target users of SoundTrAD. Specifically, the need for SoundTrAD to cater for novice designers and questions regarding whether it could cater for designers with more experience as well. The study also identified the need for further exploration into sound categorisation.

It was an interesting finding from study two that the topics, final themes and questions around target users are naturally interrelated. For example, exploring answers around the suitable mappings for SoundTrAD will involve questions that relate to the target users and the presentation of the sound design suggestions on the interface (T4). The sound classifications cannot be complex and need to be understood by people with limited musical experience. Having access to the design rationale behind the mapping choices was not considered to be necessarily important for all designers, however, it is still important that they can access it if they wish. Additionally, it is important that the designer's rationale is captured to support a systematic approach to creating a display and to support the integration of the design stages: linking requirements/cue sheet to event layout and auditioning using the timeline and to address the options for making changes in the future, or simply making the design rationale available to other designers.

## **Introduction to Chapter 7**

The next chapter documents study three. A study that saw an exploration into ways that an end-user can be better supported when using SoundTrAD. Study three involved exploration into how the three final themes; identified from the thematic analysis in study two, could be used to inform updates to the requirements gathering stage of the method, the development of the cue sheet, the timeline and to the database of event to sound mappings.

<b>Cue Sheet</b> Col.Header	Options	<b>TimeLine</b> Type of Sound	Musical Treatment	Parameters	DAFX	Transitions
Time Context Listening Mode Themes (skin)	Indoor/Outdoor Active /Passive Sport/Work/Leisure	Music/Ambience				
6.Type	Env./Location Object Character	Ambience Hard Effect Music	Melody/Motif			
7. Properties& Characteristics	Ind./Man-made Org./Human	-	Inst.:Synthetic Inst.:Acoustic			
8. Want Audio.& to Comm	How big Temperature Size Colour Amount Motion Velocity Height Age Actions		Loudness/Volume	Panning Pitch Pitch and Duration Loudness Loudness/Volume Pitch Pitch Pitch and Tempo Frequencies Pitch-shift	Spatial	
9. Behaviours	Moves Up Moves Down Remains Steady	Hard Effect	Melody:follow action Melody:follow action	Rhythm:regular		
10.Occurrences	Discrete Continuous		Length Length			
11. Mood	Neutral Positive Negative		Harmony:interval 5th Harmony:high- pitched, maj.mode Harmony:low- pitched, min.mode			
12.Transitions Does info change	Repeats Stops (error) Changes(non-res.) Changes(res.)					Leitmotif Dim. interval Dom.7th chord Scale from 7th to 8th

Table 6.1: Mappings of events/information on the cue sheet to sound suggestions on the timeline.



Part.	AD Design	Interaction Design	Composition
1	No	Yes	Yes
2	Yes	Yes	No
3	yes	yes	no
4	yes	yes	yes
5	no	yes	no
6	yes	yes	no
7	yes	yes	yes
8	yes	yes	‘?’
9	no	yes	no

Table 6.2: Experience of AD and interaction design and music composition.

## Chapter 7

# Study Three

The previous study two used a mixed methods approach to explore subjective user responses, thoughts and feelings about SoundTrAD in detail. Specifically, the study aimed to identify links between the different aims of SoundTrAD, in terms of what it can support as a method and tool, in relation to updates that were made to the method steps and tools. As a result, it was possible to identify what was successful in regards to supporting the original aims of SoundTrAD as well as the things that were less supportive and needed further development at this stage.

This chapter outlines the development and evaluation that went into a further iteration of SoundTrAD. This largely entailed applying the design considerations that arose from the results of the last study and specifically phase six of the thematic analysis. The last study identified and labelled three main themes as areas to consider for method and tool development. These were added to the the theme of creativity versus support (T1) that had already emerged from study one.

- T1: creativity versus support;
- T2: audio as part of the design process;
- T3: terminology;
- T4: interface and tool development.

These four themes were used to inform a set of design implications for developments to SoundTrAD. These design implications are outlined below with reference

to the related theme as identified in study two, phase 6 of the analysis (see figure 6.5 for an illustration of this thematic map).

- Less rigidity with regard to the prescribed requirements for the scenario and of events to be sonified. To explore T1 (support versus creativity) in regard to the level of support that the designer is given.
- Consideration of audio at an earlier stage within the design process (T2): it was felt designers, particularly those new to audio, needed to be exposed earlier in the process to some possible audio representations of what was to be presented in the display. This would improve the aesthetics of created displays due to a better understanding of how sound can represent events and actions, including managing transitions between sounds and integrating the different sound representations into an overall display. Finally, that this could lead to an enjoyable and creative experience.
- Simplification and clarification of the terminology (T3): it is proposed that this could improve usability, assist novice designers, assist the requirements gathering stage and the design of the timeline.
- Developments to the cue sheet and to the timeline. Specifically, focussing on usability in general and means to support the integration of the different stages and steps of SoundTrAD (T4). It was concluded that these developments could effect the immediate confidence of the designer when faced with SoundTrAD initially, and support the flow of the method. Additionally, the developments could provide optional access to the rationale behind the mappings and provide a way that the designer's own rationale can, in turn, be captured. It could also address issues around screen space and colour coordination.

Written below are more details on the developments that were made to SoundTrAD at this point.

## 7.1 Developments to SoundTrAD

### 7.1.1 Terminology: The Events

The previous studies have focussed on the idea that a user action and the interface object that is being interacted with, can be analysed for the feedback event this interaction produces. For example, study one asked participants to identify actions and objects within a given scenario, the relationships between these and the resulting sound that this interaction might produce. Study two included the idea of either a user or a system action triggering a piece of information to be sonified and this information being optionally classified as a continuous or discrete event.

With study two the definitions between user and system actions caused confusion in relation to the requirements of the scenario, as was exemplified by feedback from the participants. For example, P2, in response to the fact that in the scenario they were working with the hypothetical user, *“turned the system on and the electricity use was steady”*, was confused by the number of events this could be identified as, stating that *“it could be an on-off switch or the electricity (level) that [they were] trying to capture”*. Specifically, there was a confusion over the task of sonifying either the user or system action or the event this triggered and the terminology used to split these different events up. This was also concluded to be a study design error, in that the distinction should have been made clearer, as was also identified through the process of thematic analysis. As a result, at this stage, a re-examination of the literature was carried out to make sure that the potential role of the events within SoundTrAD was fully understood by the researcher. Consideration was then given to how the terminology could help define and clarify the different types of events that could be best utilised by SoundTrAD.

Below is a brief account of the literature that was reviewed at this stage to help clarify and anchor event classification and their appropriate usage within SoundTrAD.

#### **Background: A Review of Events and Status**

Events are discrete and they are action dependent (Dix & Brewster, 1994). A user or system action must occur in order for an event to take place and feedback is only

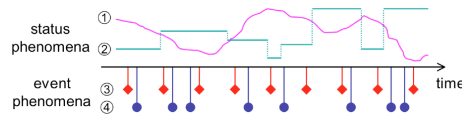


Figure 7.1: Dix's event status representation.

given when the event occurs (Brewster & Wright, 1995).

Brewster and Wright (1995) define events as either being input events (such as a mouse click) or as being output events (such as a 'beep' for example). Therefore, it is possible to argue that an event is a term that can be used to describe not only user actions and system actions but the feedback that is produced as a result of these, such as sound, light or text, and that these are therefore in need of distinction. Arguably, the lack of this distinction could be where the confusion between user actions or triggers and information event occurred in the previous study.

Dix and Abowd (1996) pointed out that some interface phenomena are more easily described in terms of events and some in terms of status. Dix added that a status-event analysis has proved to be a useful way to look at interactive systems because it is able to describe phenomena that occur in human-computer interactions, in human-human-interactions, in human interactions with the natural world and in internal computational processes (Dix et al., 2007).

Unlike an event, which is discrete and action dependent, status is any information phenomena with a consistent value. It is a system-provided representation of its current state and events can change the status information. However, it is important to note that status phenomena is not always continuous (temperature) but can also be discrete (is the light on?). The central thing to identifying status is its temporal continuity (Dix et al., 2007). The status can be sampled at discrete points, but must be continuous. Dix's figure 7.1 (p.212, 2007) demonstrates this relationship. Dix's description of the figure is as follows: *Status phenomenon labelled (1) has a continuously varying value over time, but the status phenomenon (2) has a number of discrete values, but still at any moment has a well defined value (except possibly at moments of transition). In contrast, the event phenomena (3) and (4) occur only at specific times. The two event phenomena (3) and (4) are also shown to demonstrate that event phenomena may be periodic (3) or irregular (4)*

Dix highlighted here the importance of identifying the different types of status

and event and, in particular, the importance of thinking through their behaviour and values over time.

### ***Audio Feedback***

Brewster's Event-Status-Mode (ESM) method extended Dix's Event status model to add mode as an extra dimension. This referred to the understanding that the effect or perception of an event is dependent on the context (or mode) in which it takes place. Brewster used the ESM analysis to provide design guidelines for audio feedback; to represent the events, status and mode, specifically, for the design of earcons (see chapter 2, section 2.2.3 for more detail). Brewster identified that feedback can either be transient or sustained, wherein transient would be appropriate for an event and sustained feedback would better represent status. Brewster went on to argue that sustained sounds can be 'habituated' by the listener and the user does not actively have to listen and that the sound will be perceived again only when it is changed (by an event) or the user decides to tune in. Brewster concluded by pointing out that event representations should seek to draw the user's attention, while status is merely presented, and that it should be left to the discretion of the user whether or not to pay attention to the current value of system status.

### ***A More Recent View***

Dix et al. (2007) has more recently considered how an event/status analysis might be applied to modern applications and situations. Dix references ubiquitous or pervasive computing that might utilise a high data sampling rate. He observed that when samples are gathered, the particular time of the sample, unlike an event, is not a 'special time' but rather a 'convenient time to report at' (Dix et al., 2007, p.211).

What is important about Dix's update is the observation that sampling a continuous value can be seen as a 'convenient time' to report that value, and that there is a distinction between this and the occurrence of an event at what he termed a 'special time'. In relation to this is the importance of seeing how changes in status can constitute behaviour in that 'lower level events [can] interact to give higher-level behaviour' (Dix et al., 2007, p.213). This can be interpreted by understanding that a given status can be analysed for behaviour as a result of the interaction of the discrete samples and that some 'behaviour is a combination of both status and event' (Dix & Abowd, 1996, p.2).

## The next stage of SoundTrAD Development

Four types of events were classified as suitable for use within SoundTrAD at this stage. This was based on developments to the event classification that were used in study two with an addition of a data point event:

- User action (UA): can be used to describe a user action.
- System action (SA): can be used to describe a system action.
- Data point (DP): a discrete data point whose value describes the current state of a specific parameter (very often reported with a specific frequency, such as a patient’s temperature being recorded every 5 minutes).
- Continuous (status) (CE): not an event as such, but an ongoing continuous presentation of the status of something, such as a light indicating that a kitchen appliance is switched on.

**Summary:** Figure 7.2 <sup>1 2</sup> illustrates the understanding of events and their relationships that were considered suitable for SoundTrAD at this stage in its development. To describe this figure, user and system actions can be interpreted as triggers and/or events and these can be represented through a feedback event or can trigger further events. For example, a user or system action could be represented by a transient sound or it could trigger a further user or system event or even a continuous event. In turn, the continuous event could be represented through a sustained sound or it could be sampled (‘at a convenient time’) to produce a quantifiable data point which in turn could be represented through a transient feedback event. What follows is an example which attempts to incorporate all of these possibilities.

## An Example Scenario

An email system makes use of auditory notifications of events to its users. When a user sends a completed email, if the “send” operation was successful, this triggers a confirmatory sound from the system (UA). If the “send” operation fails, this triggers

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<sup>1</sup>[\*http://www.clipartpanda.com/clipart\\_images/movie-director-shouting-action-58588826\(29/8/17\)\*](http://www.clipartpanda.com/clipart_images/movie-director-shouting-action-58588826(29/8/17))

<sup>2</sup>Illustration by Christoph Niemann:[\*http://www.popsi.com/gear-gadgets/article/2002-10/what-happens-when-your-computer-crashes\*](http://www.popsi.com/gear-gadgets/article/2002-10/what-happens-when-your-computer-crashes) (1/5/17)

a “send” operation (SA). This, in turn, triggers further attempts on the part of the system to send the email. The fact that the email continues to be unsent is an example of a continuing “failed” state of the “send” process. A designer would probably not choose to represent this in audio as it would be irritating to the user but might provide the ability to query the status on demand, for example using a keystroke (UA), of what the ongoing status is of the unsent email. The designer might however decide that it is useful to remind the user periodically, say every three minutes, that the system still has not been successful in sending the email. This could take the form of a audio notification every three minutes that the system is still attempting to send the email (DP). This would be an example of where a continuous state of the system, i.e. failure to send an email, is sampled at a convenient time, every three minutes, and reported to the user in the form of a discrete, transient sound indicating the ongoing “failed” state of the “send” process (DP). Eventually, this situation would be resolved either by an notification to the user that the system had finally succeeded in sending the email (SA), or an alternative notification that some maximum number of retries or upper time limit had been reached and no more attempts to send would be made.

The classification of events within a scenario is, to a point, subjective. The aim, however, is that this classification can offer guidance regarding what the events could be whilst also not being rigid or prescriptive. To re-iterate Benyon’s view in relation to carrying out an object/analysis on a scenario: there are ‘no right or wrong answers’, it is ‘just another way of exploring the design space’ (Benyon, 2010, p.94).

### **7.1.2 Requirements Gathering**

In line with more recent research, SoundTrAD was updated with specific attention to the requirements gathering stage. This was in order to address the issue raised in the last study about the prescribed and ‘rigid’ nature of the pre-defined options that were available as a match for the requirements. This can be exemplified in the previous chapter, p.135 when discussing topic number 5: Integration and Iteration.

This current version of SoundTrAD, as part of the requirements gathering stage, still allowed the designer to identify the behaviours and properties of events that



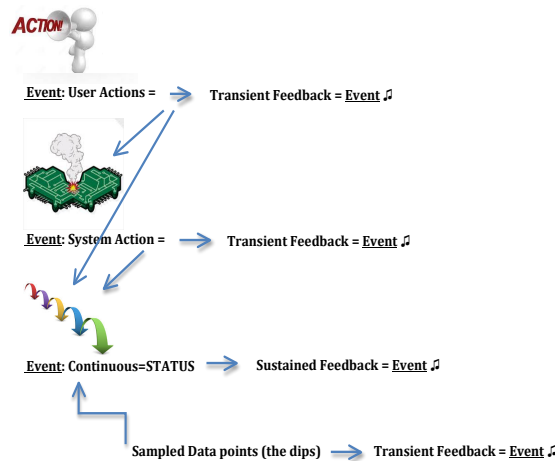


Figure 7.2: Event relationships.

needed sonifying (the UA, SA, DP or CE) in order to get ideas for the representation of the events. However, the list of selections provided in study two, table 6.1, were no longer available as options for the designer. The only requirement that was limited to optional selection was the type of event (as defined above). It was also the aim to explore if opening up the design space in this way could encourage creativity while still providing guidance on possible ideas/approaches about the AD being designed.

Listed below are the requirements that were used in the development of this version of SoundTrAD with a brief explanation of their role, alongside a short description, explaining the changes and developments that were made from study two. These are then explained in more detail after the list.

1. Describe action/event [open text box].
2. Identify type of event. Select from:
  - User Action (was trigger/interaction: with option user or system).
  - System Action (was trigger/interaction: with option user or system).
  - Data Point (was inherent with description of event as discrete).
  - Continuous-status (was inherent with description of event as continuous).
    - *Aim of development:* to get open-ended responses with room to describe the event (number 1 above) before defining it (number 2).
3. Context (was one context for whole scenario).

- *Aim of development:* each event to have its own context to cater for the fact that the context of use could change during the scenario.
4. Description, Keywords, Values (was properties, characteristics, / ‘want to know about the information?’ with a list of options. See table 6.1).
    - *Aim of development:* to have one over-arching category to encourage more individual text input and cater for multiple information or event types and not filter it according to a pre-selection.
  5. Behaviours (same as before, except had options: ‘moves up’, ‘moves down’, ‘remains steady’).
    - *Aim of development:* open-text to get wider responses and less restriction.
  6. Themes / Mood (same as before, except had options: ‘positive’, ‘negative’, ‘neutral’).
    - *Aim of development:* to have no selection options at this stage. To use these instead as categories in the database. See section 7.1.3 below.
  7. Occurrence (was discrete or continuous).
    - This is now inherent in event selection (for example an event such as a UA, SA or DP is discrete, whereas a CE is continuous).
    - *Aim of update:* to replace the time category as the means to help position the event and provide a marker to re-reference the cue sheet at a later stage. Particularly if events are being moved about (see timeline section 7.2.3 below).
  8. Transitions / Triggers (in the previous study this was, ‘does the information change and what causes this’: see table 6.1).
    - *Aim of development:* open-text to get wider responses and less restriction.

### **Explanation of the Developments:**

Describing the action and/or event (number 1 above) catered for the event being a user or system action, a continuous event or a data point. The description was subjective and the process of entering ideas here will help with the next phase

of identifying the actual event as either a UA, SA, DP or CE. Each event could be described for the context in which that event took place. In study two it was possible to describe the context for the entire scenario. However, in this study, each event had its context assigned in order to cater for changing contexts within one scenario and to generally be more flexible. Time was no longer an option with the requirements, as this could be catered for by the timeline (as is referenced below in section 7.2.3). The listening category was also removed, as this caused confusion and it was hoped that this could be supported with the sound choices available and used at a later stage in the method. Skin (theme) for the overall interface was also discarded at this stage. This could be inherent in the database and subject to sound classifications rather than than be a requirement at this point in the method. The options to select characteristics and properties were also altered. This now became a free-text option to fill out ideas for descriptions, keywords and values. The confusion previously caused by limiting choices was eliminated therefore encouraging a feeling of less restriction in the design process. Additionally, having room for free text catered for both quantitative and qualitative responses and descriptions of the events. In behaviours the options of rise, fall and remain steady were omitted. To clarify, behaviour could be associated with individual events; for example a user action ('what was it the user did') or with a status or continuous event as made up of several data points (Dix et al., 2007). However, the latter could not be broken down into individual events (as it is a summation of events) and so the free-text entry box would leave this requirement optional; once again providing support for multiple scenarios and event combinations. With themes and moods the option to select positive, negative or neutral were also omitted. Again, this was to cater for whether the designer wished to assign descriptions to the individual event or a series of events, that might have a collective mood or theme, for example. Occurrences catered for the position of the event (instead of time) and transitions/triggers for an identification of things that could link one event to another. Both of these also had free-text entry boxes and not prescribed options. In summary, categories and suggestions were moved from this stage in the method to the later stage involving the mapping of sounds in the database.

### 7.1.3 The Sounds and Mappings

#### Terminology

The last study highlighted issues with the terminology used for classifying the audio and representing sound suggestions through text. Specifically, the specialist nature of it and how this was perceived to limit the accessibility of SoundTrAD version 2 for novice designers. As a result, the terminology was simplified and the sounds suggestions re-categorised.

This version of SoundTrAD had to provide a sufficient number of sound choices for participants whilst still remaining manageable. As a result, a set of eighty sounds was created and sampled for use within the method. Multiple categories were then defined into which these sounds could then be classified. This was done in order to support different ways of accessing the design suggestions, cater for different design approaches and provide the ability to cross reference and search from multiple view points. Study two had categories on the timeline, these were now moved to the database with options for the designer to explore them. SoundTrAD, with a completed database, would ideally allow users/designers to add their own sounds.

Initially, all of the sounds were categorised under the following genres. These categories were based, in part, on the database constructed in chapter 5 and on the categories used in soundtrack composition (see section 5.4.1 in chapter 5 for the early-stage database and section 2.1.3 in chapter 2 for these soundtrack categories).

These first three categories are simply high level categories under which all the sounds can be categorised. These were introduced at this stage because very high level categories could support the designers in very quickly narrowing down the search space to within the high level category most appropriate to the sound they were seeking.

- Musical.
- Everyday.
- Mixture (musical-everyday sounds).

The sounds were then categorised according to the most appropriate soundtrack category they could be associated with. Again, these are based on the database

of mappings that was started in this research (documented in chapter 5). Further inspiration was also gathered from Buxton and Gaver's idea of everyday listening (W. Buxton, Gaver, & Bly, 1989), in order to represent a wide range of sound possibilities. For example, the idea of isomorphic sounds, where the sound is associated with the cause and the shape of the sound matches the actions that produce them. Ultimately, the overall goal was for the categories to be simple and immediately understood when using the database within SoundTrAD.

- Foley (an action sound).
- Background/environmental/Ambience.
- Musical Underscore.
- Isomorphic (whereby the shape of the sound matches the action).
- Melody/Motifs.

Further categories were then devised and within these categories there were a few audio sample examples to be utilised at this stage. The researcher populated each category with 2-10 samples. Due to the scope and limitation of this research, it was felt that this amount would populate the example sufficiently to meet the needs of this study. What follows is a description of the options presented to end-users/designers regarding the mapping of requirements onto sounds in the database.

First, there was an option to identify a sound according to its musical attributes (as in study two). This was kept as a means to represent the requirements of the event being sonified.

- Pitch.
- Rhythm.
- Timbre.
- Melody.
- Harmony.
- Spatialisation.

- Amplitude.

Secondly, there was an option to identify the sound, in reverse, according to the requirement that best represented it. This served as a way that the designer could carry out a cross-check, by coming from the other end of the event representation problem. Study two had shown that the relationship between the requirements and the sound suggestion was not sufficiently clear. Therefore, this relationship was made more explicit.

- Behaviours (increase/decrease/rise/fall).
- Themes (positive/negative/neutral).
- Descriptions/ Keywords (search for a property or physical attribute).
- Occurrences (1st, 2nd, 3rd).
- Transitions/triggers.

### **Audio in the Design Process**

This was supported by permitting access to the sounds at any point; auditioning them, selecting, mapping them to events and being able to cross reference and search at different levels. The implementation of this is outlined in more detail in the following section on tool developments.

## **7.2 Tool Development**

Updates to the cue sheet and the timeline were based, in part, on findings from study two. It was concluded that the tools needed to support the integration of the different method stages and steps, provide options for the designer to access information regarding the logic behind the mappings and support event layout.

The tools were designed to support situations where events might change order so to address issues relating to designing for use cases. The practical solution to this came from ideas from soundtrack composition practice in relation to modular composition for games. Soundtrack composition for gaming situations is frequently non-linear and modular which can be seen to be parallel with typical interaction scenarios that might often repeat but in slightly different ways. To summarise:

- The cue sheet layout was simplified:
  - The use of colour to represent the different events to support integration and usability.
  - Text boxes for entering the requirements.
  - Tick boxes for selecting the event.
- The timeline was updated with greater functionality:
  - Colour was used to represent the events to support method stage integration and general usability.
  - Options were added to move and play the audio events in order to explore the event layout and the coming together of sounds and re-arranging of events to suit different use-cases.
- A series of sound examples were added to the database:
  - Possibility to select them and add them to the events on the timeline.
  - Option to navigate the database through visual categories.

### 7.2.1 The Cue sheet

Figure 7.3 illustrates a blank cue sheet and figure 7.4 illustrates the cue sheet with a filled out example. The example was optional and could be pre-loaded onto the cue sheet to demonstrate how it could be filled out.

The interface to the cue sheet was also altered and to an extent simplified, in order to go back to the essence of the structure, in line with feedback from participants. To widen the choice of entries onto the cue sheet, text boxes were provided for event names, a tick box for selecting event types and colour to represent the occurrence of the different events. For example, the first occurrence of any event caused the row to be highlighted green, the second pink and the third blue. This was used to tie in with the representation of events on the timeline that were also represented using the same colour scheme.

	Identify action/event	Type of Event	Context	Description (keywords/values)	Behaviours	Themes/mood (binary)	Quantity and Range	Transition/Triggers
event 1 →		UA SA DP CE						
event 2 →		UA SA DP CE						
event 3 →		UA SA DP CE						
event 4 →		UA SA DP CE						
event 5 →		UA SA DP CE						
ETC								

Figure 7.3: Cue sheet (blank).

	Identify action/event	Type of Event	Context	Description (keywords/values)	Behaviours	Themes (kw)	Occurrences	Transition (trigger)
event 1 →	Turns on system	UA SA DP CE	Indoor	Turn on	on	Good	1st	trigger system action
event 2 →	Monitors electricity	UA SA DP CE	Indoor	switch to auto mode	changes	Good	1st	trigger Continuous Etc
event 3 →	Turns on appliance	UA SA DP CE	Indoors	temperature	increasing	positive	1st	trigger data point
event 4 →	Temperature reaches thr	UA SA DP CE	Indoor	3 degrees		bad	1st	trigger data point
event 5 →	Turns off system	UA SA DP CE	Indoor	turns off	turn off	bad	2nd	

LOAD / Remove EVENTS on and off THE TIMELINE

UA 1 ☐ SA 1 ☐ DP 1 ☐ CE 1 ☐  
 UA 2 ☐ SA 2 ☐ DP 2 ☐ CE 2 ☐  
 UA 3 ☐ SA 3 ☐ DP 3 ☐ CE 3 ☐  
 DP 4 ☐

Explore the sounds

Figure 7.4: Cue sheet with example.

## 7.2.2 The Database

For this version of SoundTrAD, text-based sound suggestions were removed from the timeline. The database was now used to present more information about the events and the logic behind the mappings. As mentioned, 80 different sound samples ranging in length from milliseconds to 8 seconds were included in the database. The length of the samples was inspired by the work of Zhao, Plaisant, Shneiderman, and Duraiswami (2004) and their research into suitable lengths for auditory overviews. All of the sound samples were categorised and there were only a few examples of the sounds in each category. However, a number of the sounds fell into more than one category, in order to provide a multiple view perspective.

The layout, which was in a separate window (see figure 7.5 for a screen shot of the database), supported the accessing of sounds through the use of drop down menus, options to select events, pop-up menus and meta-data regarding the length of the sounds. The categories were there to support the link between the requirements and options for mapping to sound and offer greater flexibility for navigation. In-line with the open-ended nature of SoundTrAD it was important that the database was



understood to updatable and represent a structure that can be added to.

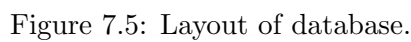
Also, in line with the multiple perspective approach provided within SoundTrAD, it was important that the database could be navigated from the starting point of any of the three fields: soundtrack composition, musical attributes and the scenario requirements (cue sheet categories). This version of SoundTrAD incorporated these important mechanisms.

Study two included the design of an initial database in which sounds were based on parallel functions between AD and soundtrack composition and could be navigated by things that composer's spot (actions, objects, locations, emotions, moods and transitions). This was not evaluated as such but presented an initial proof of concept. Furthermore, in study two the ideas were then presented according to musical type and then musical treatments. The idea, for study two, was that different requirements of the information (behaviours, properties and type) mapped to the different musical components and that, in theory, for each event there would be a suggestion for a type of sound and what to do with it.

The aim for this version of SoundTrAD was to move sound categories and navigation to the database and encourage a more flexible approach to specifying requirements, make the timeline simple and replace the textual descriptions of sounds with actual sounds samples. The sounds were there to represent examples of different possible requirements combinations.

### **Target Users and issues with the Database**

In relation to the target users, the aim of this research was to work with multiple types of users. This included people who are new to AD design and unfamiliar with the use of audio in general. End-users with limited knowledge have provided ample evidence they simply do not know where to start given the need to represent interface phenomena in sound (Frauenberger & Stockman, 2009). When catering for mixed users, SoundTrAD offered method steps and supporting tools to help organise and provide a methodical approach to the series of tasks that need to be done. However, the target population with experience could be left in theory to select their own sounds within that overall structured approach. This is not the case, however, with novice AD designers, they needed examples, suggestions and stubs which they can



use at least as initial place-holders for the sounds that will eventually populate their design. It may be that some of these turn out to fit their requirements, but in many cases the suggestion would literally serve as place-holders and either be entirely replaced by better choices or be edited in order to fit the requirements more effectively. This may, of course, be completed by a sound design specialist who takes on the initial design and provides an efficient implementation of it, or even by the same person but guided by someone who knows about sound editing/production.

This version of SoundTrAD achieved its aim of placing a person with knowledge of interaction design in a position to make reasoned decisions about where sounds should appear in the interface. In addition, it provided scaffolding to help people new to AD design, choose broadly appropriate sounds to match events. This results in a first cut prototype of the AD design, which then may benefit from someone who has audio editing/production skills to refine it for production. It is possible to draw an analogy of the idea that an interface designer could benefit in the later stages of the development of a visual interface with the services of a graphic designer to provide graphics to represent the visual components of a graphical interface.

### **7.2.3 The Timeline**

A timeline was produced to represent events visually and provide audio representations of the events. Study two had the early development of a timeline to represent the sound suggestions as text. This was considered useful but not accessible to all designers. Additionally, it was found that hearing the audio rather than reading about it was preferable. Therefore, inspired by Dix and Abowd, and due to the emphasis they place on the role it can play in a design, a visual status and event timeline was produced as a supporting ‘semi-formal diagrammatic technique’ for SoundTrAD (Dix & Abowd, 1996, p.2).

The timeline, similarly to study two, had time marked horizontally on the x-axis and space marked vertically on the y-axis. Study two had presented one event after another, but now the timeline presented multiple events vertically. For example, the top row presented user actions, the second system actions, the third data points and the fourth row represented a continuous event. It was still the case that events occurred one after the other, however multiple events could happen at the same

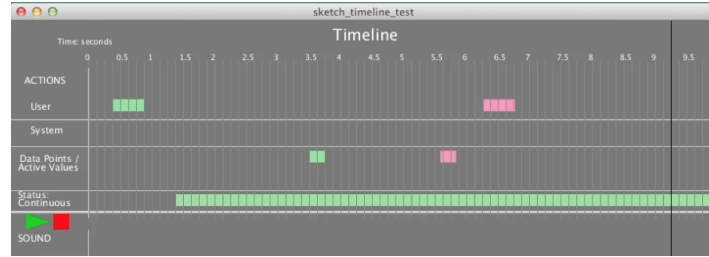


Figure 7.6: Timeline used for study three.

time. For example, user actions, system actions or data points could occur during a continuous event. The colour coordination still applied as this was revealed to be a useful feature that supported work-flow between different steps and stages of the SoundTrAD method.

The ability to move and change the lengths of the events was made available and it became possible to edit events directly as a result of interaction using the mouse. A moving playhead was added to represent the playback of the events, as figure 7.6 depicts. The timeline permitted a 10 second playback. This according to Zhao et al. (2004), is adequate time for an auditory overview (see figure 7.6 for the layout of the timeline).

## 7.3 Evaluation

### 7.3.1 Tasks

Task 1: The participants were given a set of tasks. This document is long and so the reader is referred to Appendix D, section 1, for a transcription of the information that participants were given. To summarise, participants were given two packages containing information sheets that they could read and/or listen to as a recorded version. The first package was sent to the participants prior to taking part in the study. The second package was read and listened to as part of the main study. The first information package outlined the aim and principle of the method, also introduced the participants to the study and explained what was under evaluation. The second information package contained one document with four separate parts and four separate recordings. The aim was to break up the stages of the method, inform participants how to execute the various steps and give participants a chance

to explore an example. Additionally, participants were encouraged to ask questions between the sections should they require. In summary, due to the fact that the participants had to learn SoundTrAD in a short amount of time, effort was put into designing the presentation of the method in order to make its structure and approach as clear as possible?

Task 2: The final part of the second package asked the participants to design an AD for an avalanche safety rescue system. They were presented with a design brief and a use-case scenario of someone using the system. This is outlined below.

### **Scenario 1.**

The scenario used for the study is a real-world design problem that was advertised in 2015<sup>3</sup>. The summary, required sounds and the detail concerning the user interface are directly transcribed from the advert. The use-case employed during the study was imagined by the researcher for the sake of posing a hypothetical design problem.

*Summary: Back Country Access (BCA) is a leading manufacturer of avalanche safety products, including the Tracker 3 Avalanche Rescue Transceiver. The new sounds need to be perceived as fast, clean and immediate.*

#### **Required Sounds:**

- Sound when beacon is turned on.
- Sound when switching to search mode.
- Sound when mode button is pushed down.
- Sound when mode button is released.
- A transmit sound for the fine search whereby the distance indicator is used to locate the shortest distance to the victim.
- Sound when unit turns off.

**User Interface:** User interface steps can be changed for this project.

**Use Case 1:** User turns the system on. This triggers the system into a continual fine search mode that remains until the user turns it off. During this continuous

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<sup>3</sup><http://www.auditory.org/mhonarc/2015/msg00062.html>

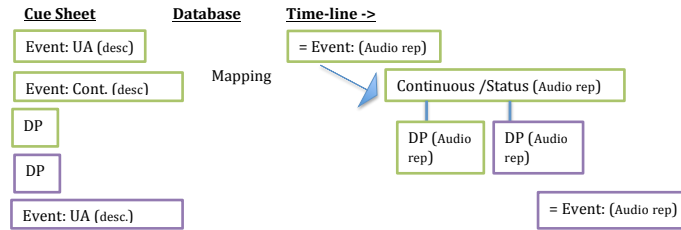


Figure 7.7: Cue sheet-timeline relationship.

event a sound is heard to indicate that the victim is ten metres away. The user then moves closer and a sound is heard to indicate that the user is zero metres away. The user turns the system off.

The figure 7.7 illustrates the relationship between the layout of events on the cue sheet and on the timeline that would be appropriate for this scenario: the first event, a user action (UA) representing the user turning on the beacon, would be described on the cue sheet before being represented on the timeline with a transient feedback sound. The second event would then be continuous to represent the continual search mode. This would be represented through a sustained sound. The next two events would both be data points (DPs) to represent the distance to the victim and once again represented through transient sounds. Finally, the last event would be a 2nd user action to represent the user turning the system off, this would be represented by a transient sound. The sound suggestion would be a Foley sound to match user actions; short musical or everyday sounds to represent the data points and a background or ambient sound to represent the continual search mode. However, this suggestion is not rigid and only example ideas are presented in the database. The participant was informed that they could document and select their own suggestions for sounds. For example, the participant could navigate and select sounds based on what requirements they input for behaviours, themes (moods), keywords or values or event types.

### 7.3.2 Data Gathering

The data was gathered through a screen capture of the final filled out cue sheets and timeline and an on-line survey made up of 9-points on a discrete visual analogue scale (Schaik & Ling, 2003). The questions were as follows:

- 1a. How useful is this method for designing audio for the interface? 1 being not at all useful, 5 neutral and 9 extremely useful.
- 1b. How useful were the requirements gathered about the events when it came to getting ideas for the sounds that could be used? 1 being not at all useful, 5 neutral and 9 extremely useful.
- 1c. How useful do you think the database is for mapping events to sound design ideas? 1 being not at all useful, 5 neutral and 9 extremely useful.
- 1d. Comment on the usefulness of the method and method steps.
- 2a. Did your design for the avalanche safety system benefit from being able to move the events and play them back during the design process? With 1 being did not benefit at all, 5 neutral and 9 completely benefited.
- 2b. Please state in what ways your design did or did not benefit.
- 3a. Evaluate how easy it was to understand the different types of events: 1 being not at all easy, 5 neutral and 9 extremely easy.
- 3b. Please comment on your understanding of the different events.
- 4a. How many scenarios do you feel could potentially be analysed using this event ontology? (1-5, marked / anchored categories: none, a few, not sure, some, many).
- 4b. Please comment on your response and give detail on any ideas you may have for the scenarios that this method could cater for.
- 5a. Would you like to add any ideas or suggestions to the database? (1-5 anchored categories: no, not sure, neutral, maybe, yes).
- 5b. Please comment on your response and outline any ideas.

- 6a. How confident did you feel using the method to create the interface sounds for the mountain rescue system? 1 not at all confident, 5 neutral and 9 extremely confident.
- 6b. Please comment on why you feel this to be the case.
- 7a. Would you like to use the method again? (3 anchored categories: no, not sure, yes).
- 7b. Please comment on your response.
- 8. SUS - method (see Appendix B).
- 9a. Evaluate the usability of the tools as they are to date: (broken up into cue sheet and timeline) 1 being not at all usable, 5 neutral and 9 extremely usable.
- 9b. Please comment on the usability of the tools as they are to date.

This study mixed types of surveys in order to get user opinions and feelings on the use of SoundTrAD as well as gather statistical data. Each of the questions had space for open-ended comments. The SUS (Brooke, 1996) was also sent to the participants (see Appendix B for a document describing this survey). For a list of the full open-ended responses please see Appendix D, section D.2).

### **Role of the Researcher**

The researcher was present during the study to observe the participants, be on hand to answer questions and to set up the screen once the training had been completed. The researcher had as little involvement during the act of creating an AD as possible. The intention was to provide less support and input from the researcher and more reliance on the help files in this study.

### **Participants**

Twelve participants took part in the study. Four of them had taken part previously in the second study (P1-P4) and eight, had not (P5-P12). The level of experience that participants had with AD design, interaction design and music was mixed. The



reason for mixing the abilities was to further explore who SoundTrAD could be aimed at and to gain insight for design ideas. Prior to the study participants were asked to write down responses to the following questions with responses ‘Yes, Some, Limited, None’:

- Have you experience of creating interfaces for human-computer-interaction (in any capacity)?
- Have you experience of creating audio for the interface?
- Have you experience with data sonification?
- Have you experience composing or arranging music?

## Demographics

Response	UI.	AUI	Sonification	Music
Yes	7	3	1	4
Some	3	1	0	3
Limited	2	0	3	0
None	0	8	8	7

Table 7.1: Levels of experience.

## 7.4 Findings and Analyses

The findings are presented below. For each question there is a description of the statistics. It was decided that presenting either the mean, mode and range of the data findings would be suitable to represent the responses. There are bar graph representations of the survey responses, which depict the frequency of responses for each point on the rating scale. Following this, a summary of the open-ended feedback for each question (if applicable) and a summary and analysis of both the statistics and responses, is presented (see Appendix D, section D.2 for the full open-ended (OE) responses that are not written here). The section then details the events that were classified by the participants and how these were laid out in the cue sheet and represented on the timeline. Additionally, there is detail concerning how the cue sheet was completed in regards to what requirements were selected and the implications these have for further design.

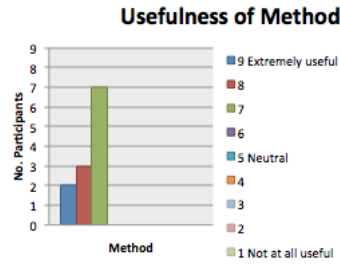


Figure 7.8: Q1a. Usefulness of the method for designing audio for the interface.

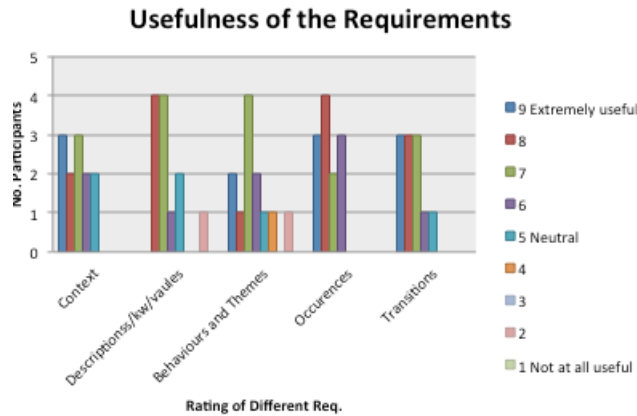


Figure 7.9: Q1b: Requirements and cue sheet.

### Question 1a: How useful is the method for designing audio for the interface?

The bar graph in figure 7.8 represents how useful the method was perceived to be. The highest response was 9, ‘extremely useful’ from two participants and the lowest response was 7, from seven participants. The mode was 7 with seven of the participants putting this as their response. The mean was 7 with a standard deviation of 0.79.

### Q1b: How useful were the requirements gathered about the events when it came to getting ideas for the sounds that could be used?

The bar graph in figure 7.9 illustrates how useful participants decided the requirements were for helping the design. The highest response for context was 9, ‘extremely useful’, from 3 participants and the lowest was neutral, from two participants. The mode was 9 and 7, with three of the participants putting 9 and three putting 7 as their response. The mean response was 7.2 with a standard deviation of 1.5.

The highest response for descriptions, keywords and values was both 8 and 7, with four participants for each score. The lowest was 2, from one participant. The mode was 7 and 8, with four participants putting 7 and 4 putting 8 for their response. The mean score was 6.5 with a standard deviation of 1.8.

The highest response for behaviours and themes was 9, 'extremely useful' from two participants, and the lowest score was 2 from one participant. The mode was 7 with four participants documenting this. The mean score was 6.4 with a standard deviation of 2.

The highest response for occurrences was 9, 'extremely Useful', from three participants and the lowest was 6, from three participants. The mode was 8, with four out of the twelve participants putting this. The mean was 7.6 with a standard deviation of 1.2.

The highest response for transitions was 9, 'extremely useful', from three participants and the lowest was 5 (neutral), from one participant. The mode was 7, 8 and 9, each receiving three responses each. One participant (P12) did not put a response for this. The mean score was 7.5 out of 9 with a standard deviation of 1.3.

### ***Summary:***

On average the occurrence category received the highest score in relation to usefulness with a mean score of 7.6 (out of 9). Transitions received a mean score of 7.5, context received a mean score of 7.2, actions, keywords and values received a mean score of 6.5 and the lowest was behaviours with a mean score of 6.4 out of 9.

### **Q1c: How useful do you think the database is for mapping events to sound design ideas?**

The bar graph in figure 7.10 illustrates how useful it was felt the database was for supporting the mapping. The lowest response was 5 (neutral), from one participant and the highest was 9, 'extremely useful', from five of the participants. The mode was 9, with five respondents. The mean response was therefore, 7.8 out of 9 with a standard deviation of 1.4.

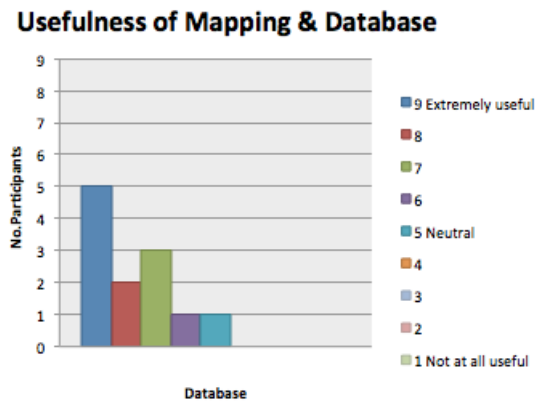


Figure 7.10: Q1c. Mappings and database.

#### Q1d: Comment on the usefulness of the method and method steps

Nine out of the twelve participants left a comment: two of the participants commented on the usefulness of the method for people who do not have a lot of experience with audio:

P5: *“I think this is a really interesting idea for designers who are not necessarily experienced with audio”*

Three participants related their responses to being able to go into further detail in their designs with reflections on future ideas for the method and tool:

P3: *“The interface and database were extremely useful. I think I would have appreciated the option to describe the actions, values and keywords more when I refer to it in six months time!”*

Two participants focussed specifically on the database and the use of audio:

P4: *“would have given a higher score if there was a more complete database and the ability to do finer edits to the sound and “maybe some integration with other database/audio editing software/platforms.”*

P7 *“It would be nice if in the final version users were able to listen to the sounds while selecting them from the drop-down box. This would help selecting the sound a person had in mind for each event.” (T2)*

Two participants commented on the time needed to learn and get used to it:

P11: *“Takes little time to get used to, may be very useful in Game development. Was quite fun overall.”*

The cue sheet was found to be the most useful for P1:

*“Based on my little knowledge and experience in AD design, I guess my participation was alright. I used the cue sheet, database and timeline (strictly) according to the instruction to complete a short audio clip for the scenario and found that the cue sheet was the most helpful material as it prevented getting lost and decreased confusion.”*

The specific columns of the cue sheet were seen as confusing for one of the participants:

P2: *“I think I got a bit confused between some of the categories, such as behaviours/themes and actions/values/keywords, and what would have to go into which text field. Also, I did leave quite a few of them empty if I remember correctly. I think one issue is that I am an extremely visual person. So, for example, if I have to design interaction I usually express myself and ideas visually in form of a story board and would so implicitly define the context, the action, and take notes of the themes. Thinking about it, this was for me personally maybe the biggest hurdle in using this part of the interface: that I cannot think and express myself creatively in a grid. However, I think this is something which I would be able to learn over time, and also probably to make my sound design ideas more explicit.”*

### **Q1: Summary of Stats and OE Responses**

The open-ended response relating to P2's and to a degree P3's responses concerning the use of text as a way to describe actions, values and keywords can be seen to relate to the larger theme (T1); the idea of text as a creative medium and the subjective nature of this as a medium. This reference from P2 is also interesting as it reflects on the sense of right or wrong (“left some blank” and “got muddled”

between categories). In regards to this particular participant and the last study, it was this participant that had an issue with the rigid nature of the requirements gathering.

The fact that two participants referred to the usefulness of the method for people not necessarily experienced with audio can be seen as a direct reflection/answer for questions around the target users.

In relation to the database, two participants (P4 and P8) referred to the usability of the interface and the GUI as opposed to its function within SoundTrAD. This relates to T4 (interface development) and the issue of the method versus the tool when it comes to gathering suitable feedback about the method steps.

P11 referred to the overall entertaining nature of SoundTrAD and how it could be used in game development. This could relate to FQ2 and thoughts around scenarios it could be applied to. P12 had a neutral response about the database but did not leave a comment. The next lowest score was 6 from P4, who commented on the need for the database to be better and more fully developed, as highlighted above. P5 left a neutral response for requirements gathering, but they did not use the cue sheet during the study and instead took notes on pen and paper.

**Q2a: Did your design for the avalanche safety system benefit from being able to move the events and play them back during the design process?**

The bar graph in figure 7.11 demonstrates that the highest response was 9, from 6 participants and the lowest was 7, from five participants. The mode was 9 with 6 out of 12 responses. The mean response was 8.1 out of 9 with a standard deviation of 0.9.

**Q2b: Please comment on what ways it did or did it not benefit**

Eight out of the twelve participants left a comment: Five participants felt that it benefited in relation to being able to audition the events, check the order they would occur in, check the overall mix and design iteratively:

P2 *“It benefited from being able to move the events because it allowed me to hear them in the order they would occur.”*

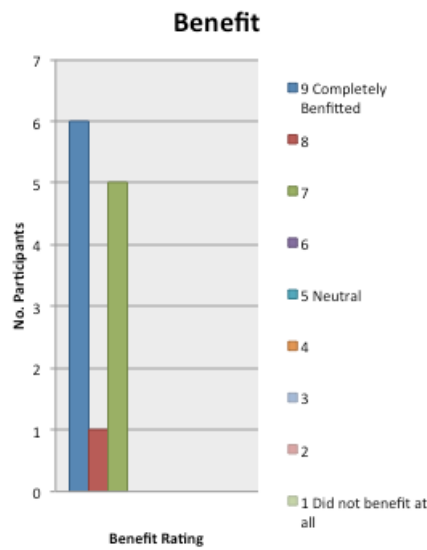


Figure 7.11: Q2a. Benefit from moving events and playing them back.

P3: *“I could check and confirm that I was happy with the chosen sound; and see how the particular sound fitted with the overall mix.”*

P5: *“It was really important, having visualised the scenario and sequence and duration of events, to be able to play it back and see if that matched what I had visualised. This is a method I would use for testing out what I had designed as I went.”*

P7: *“If referring to ‘being able to move the events on the timeline’, then yes, I think it’s useful as the user is in control of how long the whole thing is and play the sound of each event exactly when they want.”*

P10: *“to play back and check the result is necessary for me.”*

Three of the responses relate to the implementation of the timeline and in one case the database to support this aspect of the method:

P1: *“I was able to move most events in the timeline except the continuous status, which is only the disadvantage I found.”*

P4: *“It was definitely an integral part of the process, however this was hampered by the very limited database / sound generation system.”*

p8: *“It gave benefits, but I wanted to have control on length of the samples for each case, and I wanted to be able to preview sounds in the database before loading them.”*

## **Q2: Summary of Stats and OE Responses**

The feedback and the numerical data clarified that being able to work with event layout and ordering was deemed to be beneficial and the timeline helped support the design and in particular iteration and the task of ‘checking’ decisions during the process. Arguably, it was not so important to be able to move the continuous event as by its very nature it lasts for the scenario. However, there were clearly issues with the interface at this stage in its development.

### **Q3a: Evaluate how easy it is to understand the different types of events**

The bar graph in figure 7.12 demonstrates the responses.

**User action:** The highest response was 9, ‘extremely easy’ from seven participants and lowest was 4, from two participants. The mode was 9, with seven out of the twelve participants recording this. The mean was 7.8 with a standard deviation of 1.9.

**System Action:** The highest response was 9, from four participants and the lowest was 4, from three participants. The mode was 9, with four out of the twelve participants recording this. The mean was 7 with a standard deviation of 2.1.

**Data Point:** The highest response was 9, from five participants and lowest 4, from one participant. The mode was 9, with five out of the twelve participants recording this. The mean was 7.3 with a standard deviation of 1.7.

**Continuous:** The highest response was 9, from six participants and the lowest 3, from one participant. The mode was 9, with six out of the twelve recording this. The mean was 7.7 with a standard deviation of 1.9.



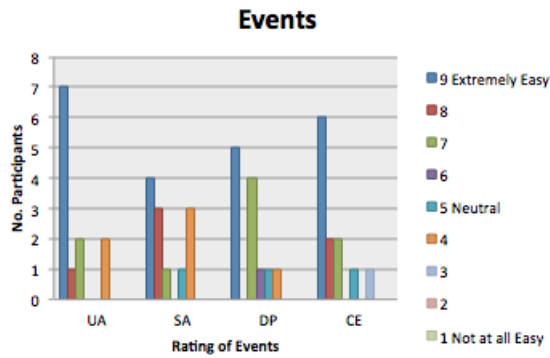


Figure 7.12: Q3a: Understand the different types of events.

### Summary:

On average, a user action received the highest score and was understood the most with a mean score of 7.8. A continuous event received a mean score of 7.7, however, it also received the lowest score. A data point received a mean score of 7.3 and a system action, a mean score of 7.

### Q3b: OE Responses

Seven out of the twelve participants left a comment. In general the events were well-understood. However, the biggest confusion came from the separation of or perhaps, function, of a user action and a system action event:

P5: *“I thought I understood UAE and SAE but then got confused when doing the scenario task. e.g. turning the system on is a user action, but the noise is a system noise acknowledging that it is now ready to use.”*

P8: *“In my scenario I was confused by turning on the system (action from the user) and system saying: ‘I have been turned on.’”*

The data point received a neutral response and this was from P1 who argued that:

*“The use of abbreviation (i.e. UA, SA, DP and CE) might fit well with the design interface but it wasn’t helpful to me especially for DP because I wasn’t clear with its full term.”*

Additionally, P2 wanted to understand the relationship between a data point event and a continuous event:

P2: “ *Very easy to understand what the different types of events stood for. But what would happen if an environmental state change, i.e. a data point event triggered a continuous event?*”

Two participants found the events easy to understand and useful:

P3: “*Events were described well and examples given in the context of a scenario. Very easy to understand.*”

P10: “*Those are simple concept and very common in everyday life. No difficulties to understand them.*”

### **Q3: Summary of stats and OE responses.**

The highest score was for understanding what a user action event is. The lowest score was for understanding what a continuous event is. The lowest responses for user and system were both 4 out of 9 from the two participants. Both participants commented, as referenced, on how they could not differentiate between the user and system actions. The confusion between UAE and SAE’s could relate to T3 and issues around terminology, or it could be related to the ambiguity between events. If people are to be creative they need to be supported in this, they need to feel confident in their selection, not confused or feeling they have given the wrong answer.

The data point received a neutral response from P1 who argued that the abbreviations (UA, SA, DP and CE) were not helpful. A continuous event received the lowest score with 3 out of 9 from P9, but they did not qualify their answer with a comment despite using one in their final design.

### **Q4a: How many scenarios do you feel could potentially be analysed using this event ontology?**

Table 7.2 shows that eight out of the twelve participants thought that many scenarios could be analysed using the event ontology. Two participants said some could be analysed and two said they did not know if any scenarios could be analysed using this ontology (P4 and P11).

Many	Some	Don't Know	A Few
7	3	2	0

Table 7.2: Q4. How many scenarios?

#### Q4b: OE Responses

Nine out of the twelve participants left a comment: Two participants felt that confusion over continuous events could limit the application for the system:

P2 *“I think quite a few scenarios could potentially be analysed using the method and some of the tools if not all. [...] However, what becomes clear thinking this through is that data point events refer to events related to a third (environmental) source (i.e. different from user and system), e.g. when vacuuming up crumbs or when it starts to rain on the windshield, and that it is not at all clear what continuous events stand for and are in relation to - they could be user generated (e.g. keeping the car at a certain speed) or a system state (e.g. vacuum cleaner running) and also be depending on an outside variable”*

P4 felt that the method could be used to design systems with *“monolithical events, i.e. clear thresholds, triggers and modes. But less good for interactions that are predominantly continuous, e.g. designing sonification of real-time gesture data”*. Similarly, P8 felt that it was *“scalable to many scenarios that have at least a start and an end.”*

Three participants gave specific examples of the scenarios it could be suitable for. Interestingly, P2 separated the method from the tool when commenting on this:

*“I think quite a few scenarios could potentially be analysed using the method and some of the tools if not all. For example, it could be used for product sound design, such as designing the sound of a vacuum cleaner or car.”.*

Two participants referred to the use of simulators and training applications:

P3: *“This tool (and database) could be used in the construction of audio for many scenarios. From adding the auditory icons to physical tools,*

*software applications and remote analysis; also in training applications such as simulators.”*

P5: *“The search analogy is a good one. Maybe medical monitoring equipment. In car navigation or collision avoidance? Hands free skiing guide to avoid rocks and advanced runs?”*

Physical exercise, sport and recreational activities were identified by two participants; P5 (above) and P9 who felt it could be used for *“Cooking, jogging or any other forms of exercise.”*

#### **Q4: Summary of Stats and OE Responses**

The above responses indicated that scenarios that are perceived as modular were felt to be suitable for the event analysis supported by SoundTrAD. However, continuous events were not clear, (as shown in the understanding of events in question two and from the comments above) and this could limit the range of suggestions. There could be possible bias due to the scenario presented to the participants. Events continued to some extent to be a source of confusion. It was concluded that one way to get round this is by providing examples of the different event types and examples of how they can be applied to different scenarios.

#### **Q5a: Would you like to add any ideas or suggestions to the database?**

Total	No	Not Sure	Neutral	Maybe	Yes
12	0	0	1	2	9

Table 7.3: Q5a. Add ideas to the database.

The table 7.3 reveals that ten out of the twelve participants would like to add something to the database, two would *maybe* like to add something and one person was neutral in their response to this.

#### **Q5b: OE Responses**

All twelve participants left a comment. These can be divided up to reflect the method steps and the tool separately: Three participants reflected on the layout of the database and accessibility to the information:

P1: Like to see Database *“arranged in categories to accelerate the design process.”*

P9: *“Put all details or items under the drop down menus and this will make users to choose what they want more easily.”*

P11: *“It might be useful to have more different system switch on/of sounds.”*

P3: *“Once the system has been fully built, you could go 1 step further and automatically allocate sound samples according to the event type (using artificial intelligence).”*

Four participants commented on wanting to be able to hear the sounds before adding the events to the timeline (T2):

P2: *“It would be easier if it was possible to listen to the sounds by clicking on them in the database (maybe have a loudspeaker icon or something to click on). Having to load the sounds to an event and then click on the timeline in order to hear it is a bit inconvenient. By then I usually had forgotten, which sound file I had selected in the first place. It might be personal preference, though, because I like to get an overview of what is available first. Also I would like to have something like a shopping basket in which I could drop sounds I like for later selection. This is at least what I did in Logic for the Sound Recording module - I would drag and drop sounds I liked and wanted to review onto empty tracks. In addition, I would have liked to be able to import sounds - I did not quite find what I wanted and what matched the sound idea I had in my head.”*

P7: *“I found there are too many sounds to choose from, that’s probably a good thing once you know how to use the system, but as a 1st time user I found it a bit hard choosing from the selection. It would help maybe being able to hear the sounds when you click on the grouping list on the right hand side, or from the drop-down menu. That would help users familiarise with the sounds quicker.”*

P10: *“It would be more efficient to listen to the samples in the database without the next step of adding them to the timeline.”*

P12: *“pre-hear the sound before load it into timeline; compare potential ones with each other more easily; knowing what is being played or uploaded on timeline.”*

Three participants reflected on more sound editing abilities and the number of sounds available:

P4: *“larger database - user tagging - simple editing: envelopes, cropping, blending - (above could be achieved by integrating with a simple audio editor like audacity, audition, reaper, etc.) - Synthesis as well as samples, where users can hook up synth parameters to data streams, especially for continuous events.”*

P5: *“Sounds that are short but you can loop them for a duration, rather than having all continuous sounds designed to be dlong. E.g. system status represented by a continuous unobtrusive low beep. Being able to change the contour of change for a continuous sound, a bit like you can drag the shape of a curved cross fade or automation in Logic.”*

P6: *“I would like to be able to add my own recordings and samples. It would benefit from a wider range initially too, but that’s more tool related than method related.”*

P8: *“More sounds, that can be easier to preview, finer control on length of samples. Colours of event occurrence in the database, once loaded. Way to control if they are loaded or not, otherwise it’s easy to get confused (or assign sample name in the timeline).”*

#### **Q5: Summary of Stats and OE Responses**

Unlike all the other questions, every participant left a comment for this question. Many of the comments related to the tool (the interface to the database) and how this can support access to the information. Firstly, there were a significant number of

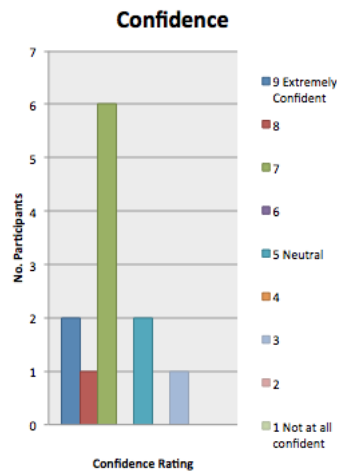


Figure 7.13: Q6a. Confidence felt using the method.

responses that related to the ability to listen to sounds as part of the design process; a direct relation to T2. P4 and P7 both commented on the amount of sounds, with P6 and P4 saying there was not a wide-enough range and P7 saying there were too many. What seemed to give P7 this impression was the layout of the database and the ability to choose sounds efficiently using the current playback facilities related to the categorisation. In summary, it could be identified that having access to more sounds would be beneficial but it is important to categorise them so that the user does not feel overwhelmed.

#### **Question 6a: How confident did you feel using the method to create the interface sounds for the mountain rescue system?**

The bar graph in figure 7.13 shows that the lowest was 3, from one participant and the highest score was 9, ‘extremely confident’, from two participants. The mode was 7 out of 9, with six participants rating their confidence as this. There were two neutral responses. The mean score was 6.8 out of 9, with a standard deviation of 1.75.

#### **Q6b: OE Responses**

Eight out of the twelve participants left a comment: Two responses related to learning and the possibility of getting more confident with use:

P1 (low of 3): *“because I wasn’t familiar with the interface. Overall*

*process was very systematic. I just need to use it a few more times to be confident with the system i.e. some more scenarios in the experiment.”*

P7 (neutral): *“Didn’t feel hugely confident, but probably would after a bit of practise with the system.”*

P5: *“Took a while to get going and learn what I needed to know, but once I had assimilated I could play quite quickly.”*

Two participants reflected on the database in relation to their confidence level:

P5: *“...Would like to be able to audition the sounds in the choice screen. The pop up telling me how long they were and quick description compensated for this somewhat. Could add the category e.g. Foley to this pop up as well. Or represent this overlay by colour? Arranging the sounds by musical, non-musical etc. was useful. Finding the sounds when you have a larger database will be important. Maybe display the sound you have chosen for each event on the timeline? I had to write it down as I couldn’t remember the number/description of each sound after I had chosen it.”*

P4 (neutral): *“The cue-sheet system was great, but as soon as I started working with sound, i.e. listening and interacting based on what I planned, I felt unable to achieve what I wanted due to limitations in the database/sound generation system.”*

There was also a reflection on the method and the tool:

P6: *“It felt like it was an easy method to use, but the tool is currently cumbersome, which did inhibit the experience somewhat.”*

2 participants felt confident using it:

P3: *“It was quick and intuitive to use.”*

P8: *“With the help of this system, the sound track will be more acceptable and easy recognized since it is created by myself.”*



## Q6: Summary of Stats and OE Responses

It is arguable that confidence is related to the familiarity with the method and tool. If this correlation is true, then potentially users will become more confident with use. Every participant would like to use the method again (see next question). There were two neutral responses but their comments imply that they were aware of feeling confident with some parts and not others, or that they would get confident over time. This was also the case with P1 who scored it 3 out of 9. In summary, confidence could be supported with a better layout of the database and with practice. The method in principle was potentially good in relation to confidence and the cue sheet was also perceived as systemic which seemed to support confidence.

## Q7a: Would you like to use the method again?

Table 7.4 shows that all participants would like to use it again.

Total	No	Not Sure	Yes
12	0	0	12

Table 7.4: Q7a. Like to use method again?

## Q7b: OE Responses

Seven out of the twelve participants left a comment. Two participants related their responses to another development or iteration of the method. One specifically referring to the interface:

P1: *“Yes if the interface is somehow simpler. I knew that this experiment was purely focused on the method, not interface design. But when there is a lot of information (e.g. buttons, texts, frames) on the screen and not easy to find it can distract the method flow. I suppose when the interface becomes “transparent” I could be benefit more from this well designed structure.”*

P5: *“I would like to see the next iteration and have another play.”*

Three participants referred to the intuitiveness and benefits that comes from the familiarity and efficient time it could take to build a design:

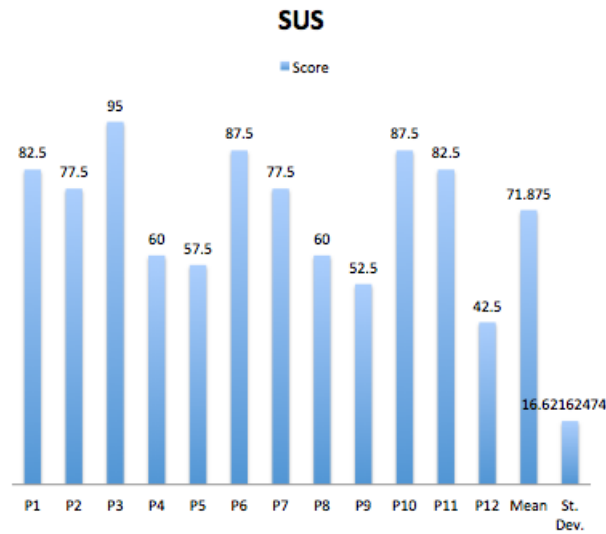


Figure 7.14: Q8. SUS usability of the method.

P2: *“The method builds upon principles I know from other design programmes, such as Adobe Flash. So it is quite easy for me to relate to it in general.”*

P3: *“As before, it was quick and intuitive to use.”*

P10: *“I think this system could save a lot of effort when making a sound track for many type of events.”*

P6 commented that if they *“needed to create an audio interface [they] would do it this way again”* and P7 claimed that it was *“very usable and enjoyable too.”*

### Q7: Summary

Everyone wanted to use the method again, however, it is clear that another iteration would be necessary.

### Q8: SUS

Brooke’s SUS scale was used (Brooke, 1996), in order to maintain consistency between studies. However, the questions were focussed in that the word ‘system’ was changed to ‘method’ in order to try to separate confusion over method, tool and interface development.

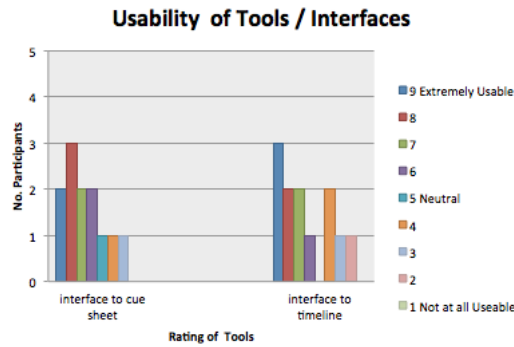


Figure 7.15: Q9a. Usability of the tools and interfaces.

## SUS Summary

The highest score was 95 and the lowest was 42.5, the mean score was 71.9 with a standard deviation of 16.6. There was a larger range in responses resulting in high deviation from the mean. This reflects the range in how usable SoundTrAD was found to be. One possibility could be the fact that the SUS scale evaluated the usability of SoundTrAD as a system, at this stage. It may be that there is a disparity between the usability of the tools and the usability of method steps and stages, and that this high standard deviation reflects this.

### Q9a: Evaluate the usability of the tools as they are to date

Figure 7.15 shows that the lowest response to the cue sheet was 3, from one participant and the highest was 9, 'extremely usable', from two participants. The mode was 8, with three out of the twelve participants stating this. There was one neutral response. The timeline received a low response of 2, from 1 participant and a high of 9, 'extremely usable' from three participants. The mode was 9, with three participants stating this.

The mean score for the cue sheet was 6.7 with a standard deviation of 1.9 and the mean score for the timeline was 6.3 with a standard deviation of 2.5.

### *Summary:*

On average, the cue sheet as a tool rated higher with a mean score of 6.7 out of 9. The timeline received a mean score of 6.3 but had a fairly high standard deviation of 2.5.

### **Q9b: OE Responses**

9 out of 12 participants left a comment. These are divided into the separate tools.

#### **Cue Sheet:**

P1: *"The text was too small"*

P2: *"Cue sheet: As I mentioned before, I got a bit confused with the different categories and with what needed to go where. Also as mentioned before, I am used to working visually so I would probably rather go for a mind map than a table, especially when it comes to interdependencies between events."*

P3: *"The cue sheet was a simple few clicks - fast and performed as expected."*

#### **Timeline**

P3: *"The timeline was a great visual cue that you could move around audio events in the space."*

P2: *"Timeline: I am somehow missing markers on the timeline because the time given at the top does not have actually any meaning - how (the sequence and timing) the sound files are played depends on the occurrence of events not necessarily the time in seconds."*

P4: *"The timeline needs some polishing in terms of user interaction."*

P8: *"Timeline should have some improvements in the control of the length, positioning and playback of the samples."*

#### **General**

P5: *"Had some problems with not being able to resize bars and there are too many separate screens to manage just now, maybe why I missed the cue sheet and went for pen and paper!"*

P6: *“Currently the cue sheet has limited text editing functions (you need to click directly in the box to type, even when tabbed to the box, and it doesn’t accept commas etc), and the timeline seems fragile/temperamental, but in full working order this would be a great tool. The sound should match the event length, either cropped or repeated to fit.”*

P10: *“I think both of the cue sheet and the timeline panel are necessary procedures in this system.”*

### **Q9: Summary of Stats and OE Responses**

Both of the lowest scores of 3 (for the cue sheet) and 2 (for the timeline) were reported by from P6. Their comments relate to interface issues and not to the method in that they appreciated that given a better tool it would be great to use. The cue sheet was seen to be good but some of the options for requirements caused confusion. Visually the timeline was perceived to be good, but needs updating in terms of supporting user interaction. Some of the above negative comments were inevitable given the prototypical nature of the tool, but the concepts of the tools were generally well received.

#### **7.4.1 Participant Designs**

##### **Reflections on the Events**

The scenario presented to the participants was made up of five events. The interpretation of this quantity of events was subjective, however, it was hoped that; a) this number would be identified, b) the correct or ideal type of events would have been selected or in the very least, users would be consistent in the types selected and c) the timeline layout produced by users would have been similar for all participants.

The ideal event selection according to the scenario would have been a UA (to reflect user tuning system on), CE (continual fine search mode), DP (indication that victim is zero meters away), DP (indication that victim is ten meters away), UA (user turning the system off). Table 7.5 and the overview listed below, outline the number of events that each of the participants chose, the type of events, the similarities between the events selected in the cue sheet and the events placed on

Part	Number	Events CS	Event TL
1	5	UA,CE,DP, UA,UA	UA, [CE,UA],DP,UA
2	5	UA, UA, SA, DP, DP	UA, UA, SA, DP, DP
3	5	<b>UA, CE, DP, DP, UA</b>	<b>UA, CE, DP, DP, UA</b>
4	5	<b>UA, CE, DP, DP, UA</b>	<b>UA, CE, DP, DP, UA</b>
5	5	n/a	UA, CE, DP, UA, UA
6	5	CE, DP, UA, UA, DP	<b>UA, CE, DP, DP, UA</b>
7	5	<b>UA, CE, DP, DP, UA</b>	<b>UA, CE, DP, DP, UA</b>
8	4/5	SA, CE, DP, DP	SA, CE, DP, DP, SA
9	8	UA, CE, UA, SA, UA, SA, DP, UA	UA, SA, CE, DP, UA, SA, UA
10	5	<b>UA, CE, DP, DP, UA</b>	<b>UA, CE, DP, DP, UA</b>
11	5	UA, CE, UA, DP, DP	<b>UA, CE, DP, DP, UA</b>
12	6	UA, CE, DP, DP, DP, UA	UA, CE, DP, DP, DP, UA

Table 7.5: Identified events and their layout.

the timeline; plus their subsequent layout.

## Identified Events and Their Layout

### *Overview*

Participant 1 identified the correct amount of events and had the same on the cue sheet and the timeline. The first was a user action followed by a continuous and then a data point. However, they added in an extra user action to represent the ‘release’ of the button and a user action to represent the user moving towards the victim. Participant 2 identified the correct number of events and had the same on the cue sheet and the timeline. They started off by marking out two user action events to mark turning on the system. They had the two events to represent one because they wanted two sounds to indicate this action. The continual search mode was represented through a system action which they lengthened on the timeline. The two data point events represented the victim being zero meters and ten meters away. Participants 3 and 4 both identified the correct number of events and had the same on the cue sheet and the timeline. They also identified the correct event types and had a correct layout. Participant 5 identified the correct number of events on the timeline, but did not use the cue sheet during the study. The first was a user action followed by a continuous and then a data point. However, they then created 2 user actions. Participant 6 and 11 both identified the correct number of events and had the same on the cue sheet and the timeline. They also identified the correct event types and had a correct layout. However, whilst the order was correct in the timeline, they filled the order differently out on the cue sheet. This reflects on the

tool and how it supports the idea of SoundtrAD working with different use cases and being able to change the order of events. Participant 7 identified the correct number of events and had the same on the cue sheet and the timeline. They also identified the correct event types and had a correct layout. Participant 8 marked out four events in the cue sheet and five events on the timeline. A system action was used to represent the user turning the system on and another for turning off (on the timeline but not marked in the cue sheet). A continuous event was used to represent the continual fine search mode and two data points to represent the victim being 0m and 10m away, respectively. So in summary the timeline was accurate but with system instead of user actions representing the system being turned on and off. Participant 9 identified eight events on both the cue sheet and the timeline. A user action and continuous event were used to represent the user turning it on and this triggering a continual search mode. A user action was then used to reflect the user moving to the victim before a SA was used to represent the system reporting the distance. Another UA was used to represent the user moving toward the victim and once again a SA was used to represent the system reporting the distance. A DP was then used to represent a ‘successful’ rescue and a user action to turn the system off. Participant 10 identified the correct number of events and had the same on the cue sheet and the timeline. They also identified the correct event types and had a correct layout. Participant 12 identified six events on the cue sheet and the timeline. The order of events was correct except they identified an extra DP event to represent the user ‘getting closer’ to the victim.

### ***Summary***

Six out of the twelve participants identified the correct number of events and got their layout correct on the timeline. Two of these filled out the cue sheet with these same events in different orders. This highlights how the cue sheet is useful for describing and laying out events in an order to suit the designer, but the timeline can be used to correctly represent the layout of the events in the scenario. On two occasions system actions were chosen to represent user actions and in one case, a system action was used to represent a continuous event.

The figure 7.16 is an example of a filled out cue sheet and timeline. Tables 7.6

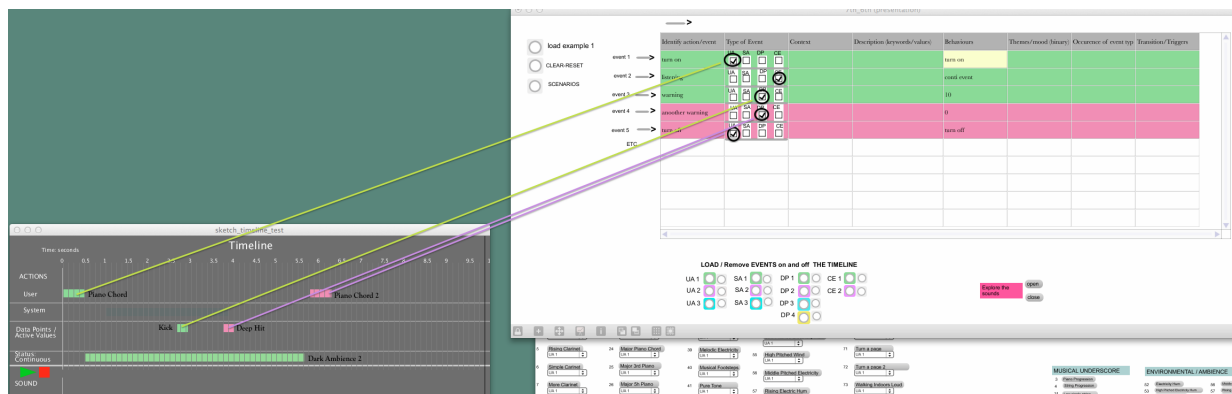


Figure 7.16: Example of participant completed cue sheet and timeline.

and 7.7 contain the completed cue sheets from all twelve participants.

## 7.4.2 Summary and Discussion

This study aimed to take the following themes identified in study two and explore and evaluate updates to SoundTrAD in relation to these.

T1 (creativity v support).

T2 (audio in the design process).

T3 (terminology).

T4 (interface/tool support).

Developments were made to the requirements gathering stage and the cue sheet as a tool to support this. Developments were also made to the mappings and the database, the layout of events and the timeline. Participants were given a real-world design problem and asked to use SoundTrAD to create an auditory display. A set of questions were asked around usefulness, usability and comprehension. Ideas for applications and updates were also gathered in order to get both simple statistics and open-ended feedback regarding the success of the updates to SoundTrAD.

## Summary of Findings

SoundTrAD as a method was generally seen as useful for people without experience of AD design. There were issues around the usefulness of the database and being able to listen to sounds (T2). The designs created benefited from the timeline because it supported iteration and the checking of decisions during the design process, however some glitches in the interface to the timeline were felt to limit its potential. In general



P	Identify Action/Event	Event Type	Context	Desc./KW/Values	Behaviours	Themes/moods	Occ.	Trans(triggs)
1	Turn on Beacon	-	mountain	-	Good	Electronics	1st	yes
1	Switch on search mode	CE	mountain	Continuous sound	Good	Electronics	2nd	yes
1	Indicator	DP	the area 10m away	10m away sound	Bad	-	3rd	yes
1	Release button	UA	-	NO sound stop	Rushing	-	4th	no
1	User moving towards	UA	-	human running	-	footsteps	5th	yes
1	Turn off the system	UA	-	-	-	-	-	-
2	sound when beacon is turned on	UA	-	-	-	-	-	-
2	sound when beacon turned on	UA	-	-	-	-	-	-
2	Continual search mode	SA	outdoors	scanning search mode	change pitch when detected	rise/happy when human found	1st time	-
2	sound when person is detected	DP	outdoors	ding when human is detected	plays the noise otherwise	happy	1st time	-
2	sound when user is 0m away	DP	outdoors	play when reach human	happy, good, rising	good rise	1st time	-
3	system ON	UA	silence	on	positive on	-	once	triggers search mode
3	search mode	CE	potentially user detection	searching	awareness	radar	continuous	user detection
3	user 10m	DP	search mode on	detecting	alert far off	falls or rises depending	first	further detection happens
3	user 0m	DP	search mode on	detecting	alert-close	falls or rises depending	second	-
3	system off	UA	search mode on	off	closing down	n/a	once	-
4	User turns system on	UA	indoors or outdoors	Trigger from off to on	Boolean change off/on	its DEFINITELY on	1	yes
4	Continual search mode	CE	Background to allow for figuration	idle standby (until someone body is found)	no change	increased level of security	1	-
4	Victim is found	DP	Foreground event	Distance and 'victim located'	Trigger event and distance	urgency	1	-
4	Victim is 0m away	DP	Foreground event	Distance and 'target reached'	Trigger event and distance	Accomplishment	2	-
4	user turns system off	UA	-	shut down system	Boolean on/off	safe shut down	2	-
5	-	-	-	-	-	-	-	-
6	Continuous	CE	search and rescue	System is on and active	-	practical functional	continuous	-
6	distance indicator	DP	periodic distance indicator	system indicates current location	pulse indicating progress towards or away	a pitch change to indicate distance	pulses	needs to override the active system sound
6	System ON	UA	user turns on system	booting up	progression	-	1	user turns on device
6	System OFF	UA	user turns off system	shutting down	digression	-	1	user turns off device
6	Distance indicator	DP	as above	system indicates current location	-	-	a pulse indicating progress towards or away from 'victim	-

Table 7.6: Completed cue sheets participants 1-6.

P	Identify Action/Event	Event Type	Context	Desc./KW/Values	Behaviours	Themes/moods	Occ.	Trans(triggs)
7	System on	UA	-	-	-	-	1st time play once	triggers search mode
7	Search Mode on	CE	-	-	-	-	continuous	-
7	Distance to Victim 10m	DP	-	-	-	-	1st time play once	-
7	Distance to Victim 0m	DP	-	-	-	-	2nd time play once	-
7	System turned off	UA	-	-a	-	-	once	-
8	turn system on	SA	-	on	-	-	-	-
8	continual search mode	CE	outdoor	-	standby	-	-	-
8	victim 10m away	DP	outdoor	something found	recall attention	-	-	-
8	victim 0m away	-	-	-	-	-	-	-
9	Turn on the system	UA	outdoor	-	Rise	Good	1st	no
9	Monitor the rescue	CE	outdoor	searching	rise	good	1st	no
9	Move to the victim	UA	outdoor	n/a	Rise	Good	1st	no
9	Report the distance	SA	outdoor	n/a	Rise	Good	1st	no
9	Move to the victim	UA	outdoor	n/a	Rise	Good	2nd	no
9	Report the distance	SA	outdoor	n/a	fall	Good	2nd	yes
9	succeed in rescue	DP	outdoor	n/a	Rise	Good	1st	yes
9	Turn off the system	UA	outdoor	n/a	fall	Good	1st	no
10	turn on	UA	-	turn on	-	-	-	-
10	listening	CE	-	conti event	-	-	-	-
10	warning	DP	-	10	-	-	-	-
10	another warning	DP	-	0	-	-	-	-
10	turn off	UA	-	turns off	-	-	-	-
11	user turns sys on	UA	-	-	-	-	-	event 2
11	sys on	CE	-	-	-	-	-	-
11	user turns sys off	UA	-	-	-	-	-	stop event 2
11	10m	DP	-	-	-	-	-	event 2
11	0m	DP	-	-	-	-	-	event 2
12	turn on	UA	-	-	press a button	good	1st	-
12	Search mode	CE	-	-	moving	good	1st	-
12	getting closer	DP	-	-	moving	good	1st	-
12	getting right position	DP	-	-	moving	good	2nd	-
12	getting further	DP	-	-	moving	good	3rd	-
12	turn off	UA	-	-	moving	good	2nd	-

Table 7.7: Completed cue sheets participants 7-12.

the events were well understood. Once again, however, there was confusion between UA and an SA. This was also reflected in the event layouts, where system action was used to classify the user turning the system on or off. There was also confusion between a system action and a continuous event, due to the fact that both can be interpreted as relating to the system (see table 7.5). It was felt that many scenarios could be analysed using this event ontology.

Everyone commented on how they would like to add to the database in terms of content and in terms of design recommendations. This demonstrated that this was perhaps the area of the method that people felt needed addressing as well as affirming its importance and centrality to the AD design process.

It was clear that the ability to listen to sounds before assigning them to events was popular (T2). Additionally, the layout of the database and the categories also needed to be addressed as a result of this current implementation; only sounds categorised under genre could be played. The layout of the database was also an issue in relation to a lack of confidence felt by participants. For example, both P4 and P5 commented on the limitations of the database (P4) and how they would want to expand the database (P5) when providing feedback on how confident they felt using SoundTrAD. It was also the case that confidence levels were higher in relation to the systemic nature of the method and would increase with practice and exposure to SoundTrAD. All of the participants wanted to use it again, highlighting that in theory confidence would increase. Importantly, however, this could be demonstrate that participants felt SoundTrAD to be useful and relevant.

The event layouts demonstrated that on average SoundTrAD lead to fairly similar event identification and event layouts, and yet it still supported creativity.

The cue sheet was therefore, successful in supporting the capturing of individual design ideas whilst also supporting the designer in selecting events. For example, the responses were diverse as can be seen from the completed cue sheets shown in tables 7.6 and 7.7, but on average designers selected similar events for their designs.

## **Limitations**

The limitations of the study included a lack of structure in the database. It was intentional that the structure was flexible in order to explore how participants nav-

igated the database, however, the navigation was affected due to the fact that only some of the categories had sound examples that could be directly played. On average, only the categories with examples were looked at and as such, the other categories could not be analysed for how well they supported SoundTrAD.

There were also limitations in the questions that were asked after the study. It would have been useful to ask participants to comment on the usability of the database as a tool, at this stage. They were asked about the cue sheet and the timeline and so having evidence about the usability of the database would have helped compare and contrast the success of the tools.

### **7.4.3 Design Implications and Future Work**

Study three revealed that transitions and triggers could be removed from the requirements and from the cue sheet as this was found to be the least used requirement. Arguably, this feature is inherent in the timeline. The event description, behaviours and mood categories were found to be ambiguous. It could be useful to find ways of ensuring that the designer feels confident entering text while, once again, supporting creativity. Therefore, an all-purpose description category could be added to the cue sheet.

Event classification and terminology proved successful and should remain in the design. The inclusion of examples could further support classification and comprehension. Sound categories need to be tidier and easier to understand.

In relation to the target users, it was clear that SoundTrAD was increasingly beginning to support a novice designer. The event ontology could support a wide range of scenarios, however, there needs to be clarity regarding the role of the continuous event in this method. The work that was done regarding sounds and mappings still needed to be clarified and reflected upon for its suitability with SoundTrAD.

## Chapter 8

# Study Four

The previous chapter detailed study three, which saw further development and evaluation of SoundTrAD. The design principles that guided the developments to the method steps and tools were based on a set of themes that were devised as a result of study two. These are illustrated in figure 6.5. For clarity, the themes are listed below:

- Creativity versus support (T1)
- Audio in the Design Process (T2)
- Terminology (T3)
- Interface and Tool development (T4)

The updates documented in the previous chapter included simplification of the requirements gathering stage and the cue sheet. This created clarity concerning how the different method stages link and integrate and gave more freedom to the end-user/designer. Additionally, a database of 80 example sounds was introduced and categorised in order to enable designers to select and experiment with real sounds much earlier in the design process. The intention was to address issues that had arisen around how users can access the sound design suggestions and in turn address the general usability of SoundTrAD. The previous study also introduced the creation of an interactive timeline to support event layout and the potential to work with use-cases. A third study was carried out and this resulted in the following findings and design implications:

- Events
  - There were outstanding issues with the event terminology and definitions; specifically between the understanding of the difference between system and user events (T3).
  - Event ordering and reordering is supported by the timeline.
- Scenarios
  - Descriptive scenarios where events are made explicit in respect of their initial order helps the correct layout on the timeline.
- Requirements Gathering
  - The requirements gathering stage does not need to gather information regarding transitions and triggers as this was a very little used feature, in terms of the amount of participants that entered text for this requirement. Six out of the twelve participants did not enter any text at all.
  - The occurrence category was also determined to be unnecessary as it was also not often used and could be built into the layout on the cue sheet and the presentation of events on the timeline. Three out of the twelve participants did not use it.
  - An all-purpose description category could be a simpler way to capture designers qualitative ideas regarding events and sound ideas.
- Mappings
  - The objective of the database could be more explicit. Specifically, as a result of a clearer study design and better structural layout of the database. As a result, its subsequent role within SoundTrAD, as a supporting tool, could be better understood alongside how it can be updated and populated.
  - Being able to access sounds from different parts of the database is useful but some guidelines to help the designer access these would make these easier to use.
- Tool

- The interactive timeline now functions to support the two requirements (occurrences and transitions/ triggers) without the need for text or identification on the part of the end-user/designer. This, in turn, could make it easier and less dependent on text entry (an issue that occurred for one participant in particular) (T4) End-users/designers can however still add text by way of documentation if they wish to.
- Creativity is, in part, supported through the layout of the cue sheet while it also serves as a suitable place to document ideas and design rationale (T1).
- The use of colour was beneficial to help support navigation between the tools and, as a result, between the method stages they support (T4)
- Audio in the design process (T2):
  - Has been used and is successful but can still be improved further.

## 8.1 Addressing Further Questions

Study two in chapter 6 had outlined specific questions relating to the target users of SoundTrAD and potential application areas for SoundTrAD that were subsequently addressed during the thematic analysis (see chapter 6, section 6.2). These were derived from the overall aims of what SoundTrAD could support as a method and tool, and so were felt to be important questions to address for its design. These are reflected upon below in regards to what has been addressed already and how providing answers to them, at this stage, helped the final development to SoundTrAD.

### Who are the Target Users?

In order to address the need for SoundTrAD to cater for novice designers (and answer the question around whether SoundTrAD can cater for both novice and expert users alike), studies one, three and four used participants with mixed backgrounds in regard to their experience of AD design and music composition. The themes that emerged from study two (T1, T2, T3 and T4), which only included participants with interaction design experience, all needed to be addressed when trying to identify the target audience: no matter who the end-user, they needed to feel they can

be creative but not overwhelmed and not restricted or confused by using SoundTrAD (T1). The simplification of terminology (T3), has been, and can be addressed further to improve usability. It is particularly important that those users with or without interaction design experience who are new to using audio can find SoundTrAD accessible. Integrating audio into the design process (T2) helps to support a novice user and has been successfully implemented to a degree with the updates; however, this can be an even more central part of the design process. The tools and the emphasis placed on their usability (T4) also support this principle aim of SoundTrAD but this can be taken further.

In summary, SoundTrAD should cater for people without AD design experience whilst not inhibiting users with AD experience.

### **What Scenarios can be SoundTrAD be used for?**

In theory, SoundTrAD can cater for a wide range of applications and scenarios. The previous study clarified an event terminology that could potentially fit a wide range of scenarios while not limiting event interpretation or creativity. Additionally, it has been demonstrated that SoundTrAD also supports scenarios that contain composite events and that this combination is a central feature of the method.

It is therefore proposed here, that an example of a suitable application for the method would be process monitoring. The reader is referred back to chapter 2, section 2.2.2, for a fuller account of process monitoring and ADs. To summarise, often process monitoring is time-based, supports parallel tasks and combines events (Hildebrandt & Rinderle-Ma, 2013). Process monitoring can be interactive or not, it combines different types of audio from ambient soundscapes to auditory icons, to earcons and can be seen to be very useful for many applications in the areas of ubiquitous computing and the Internet of Things, such as the control and monitoring of home appliances and energy consumption (Vickers, 2011; Hildebrandt & Rinderle-Ma, 2013).

### **What Sounds?**

The studies have highlighted, perhaps not surprisingly, that it is impossible to provide a pre-existing sound mapping for every option and every user's/designer's idea



or vision. However, the sample of eighty sounds used in study three was an attempt to provide a manageable range of options without overly restricting the range of available design options. The studies have explored this possibility in order to get ideas about the use of sample sounds and understand the parameters the method could work within. However, it was concluded as a result of the three user studies, that SoundTrAD needs to be consistent in the mapping principle it supports. Clearly there is a trade-off here between providing enough sounds in the database to provide an adequate design space, while keeping the whole thing manageable and approachable to novice AD designers. Limited options at this stage could demonstrate the potential for further population of a database. This also directly addresses issues around the target users, in that populating the database with a relatively small to medium-sized population of sounds could help make the method accessible for novice designers while also providing sufficient sounds to provide a proof of concept for more experienced designers. Specifically, if it was understood that the database can be expanded and updated and the method framework extended.

In summary, whilst the logic behind the mappings needs to be clear, it is not necessary to provide a mapping for every possible option. It is important to give the user a sense of control, confidence and creativity as well as a sense they have options to suit their design ideas, without feeling like they are limited in the options available to them.

Based on process monitoring scenarios, the sounds suggestions are generalised at this point to suit the applications of scenarios that fit into this category. These guidelines are taken as underlying principles for the mappings used in SoundTrAD. These principles are taken from a review of literature reviewed by Hildebrandt and Rinderle-Ma (2013). They address what should be taken into account when ‘designing sonifications for the real-time monitoring of processes that are based on mainly qualitative, event-based data’ (Hildebrandt & Rinderle-Ma, 2013, p.327):

- ‘Users should be able to customise the mapping from data to sound’.
- ‘If concrete auditory representations for the occurring events are available, the use of Auditory Icons can produce positive results’.
- ‘When occurring events are mapped to Earcons, complex timbres (possibly

based on real-world instruments) should be preferred over simple timbres (like sine waves)’.

- ‘The Earcons should take concepts from the areas of motif design and melodic contours into consideration and adhere to “musical” concepts (such as the western tonal system)’.
- ‘If motifs are being applied, they should differ not only in pitch but also in rhythm and intensity’.
- ‘Different concepts can be conveyed by using different motifs (possibly hierarchically structured) and/or different timbres’.
- ‘In general, rhythm and percussion should be included in sonifications’.
- ‘Continuous sounds (such as drones) should be used to convey the duration of ongoing activities’.

The above guidelines were used in the final implementation of SoundTrAD. It was felt that they are general enough but also address early proposed parallels between soundtrack composition and AD (see section 5.4) and ideas that have been proposed throughout the thesis. For example, the focus on the association between concrete auditory representations such as sound effects and auditory icons to represent events. The parallel between the use of earcons and the idea of a motif to represent occurring events. In relation to this, suggestions that musical melodies and ideas from western harmony be used to build these motifs and represent the events. Additionally, the idea that these motifs should alter in melody, pitch, harmony and instrumentation in order to represent events.

In general, the concept that musical constructs benefit and can be layered alongside everyday sounds and ambient background sounds. This can be constructed and layered to build a soundtrack that users can customise when mapping.

## 8.2 Developments to SoundTrAD

The following section accounts the developments that were made to this version of SoundTrAD incorporating what becomes referred to and evaluated as, a ‘system’.

This is not to imply that this version of the SoundTrAD method and its supporting tools is in any sense final. Chapter 9 contains ideas for future work at all levels of the project. However, it was considered that the method and tools had, at this point reached a relatively stable level, sufficient for a final evaluation within the scope and timescale of this PhD research.

### 8.2.1 Requirements and Data Gathering

Study three showed that there was an element of confusion regarding comprehension of some of the events. Specifically, how the requirements can map to the events and which events are perceived to be most suitable, within a given scenario. As a result, there was a clear need for examples of the different events and demonstrations of how they could be used in a hypothetical design problem.

The cue sheets that were completed from study three were, therefore, analysed further to help clarify event terminology and classification. The descriptions of the events were categorised according to whether they could be associated with a ‘start’, ‘stop’, ‘threshold’ or a ‘state change’. These associations were based on research by Hildebrandt and Rinderle-Ma (2013). The authors believed that a sonification of all the different events that occur during process execution (such as the starting and stopping of processes) can enable users to anticipate crucial situations before they occur. They also argued for the importance of identifying event-based qualitative data, whereby for each event that occurs one log entry is created, which contains an activity that has been performed, a time-stamp and an assigned user. The events they identify are ‘start’, ‘stop’, ‘threshold’ or ‘variable change’. This analysis of the events, descriptions, behaviours and themes/moods, can be seen with the highlighted text in tables 8.1 and 8.2 where the associations have been notated as start, stop, threshold or state change events.

It was hoped that the existing protocol of UA, SA and DP could be related to these types of events as, what Hildebrandt and Rinderle-Ma (2013) called, associations or causes. The aim was to support the designer in gathering and documenting both qualitative and quantitative data about the events, whilst also supporting the understanding of understanding what UA, SA, and DP can be associated with. It was found that descriptions were easily classifiable as start, stop, state change or

P.	Identify Action/Event	Event Type	Desc./KW/Values	Behaviours	Themes/moods
1	Turn on Beacon [start]	UA	-	Good	Electronics
1	Switch on search mode [start]	CE	Continuous sound	Good	Electronics
1	Indicator [threshold]	DP	10m away sound	Bad	n/a
1	Release button	UA	no sound stop[stop]	Rushing	n/a
1	User moving towards	UA	human running	n/a	footsteps
1	Turn off the system [stop]	UA	Turn system off[stop]	n/a	n/a
2	sound when beacon is turned on [start]	UA	-	-	-
2	sound when beacon turned on [start]	UA	-	-	-
2	Continual search mode	SA	scanning search mode	change pitch when detected [state change/threshold] plays the noise otherwise	rise/happy when human found [state change/threshold] happy
2	sound when person is detected [state change/threshold]	DP	ding when human is detected	happy, good, rising	good rise
2	sound when user is 0m away [threshold]	DP	play when reach human		
3	system on [start]	UA	on	positive on [start]	-
3	search mode	CE	searching	awareness	radar
3	user 10m	DP	detecting	alert far off	falls or rises depending [threshold]
3	user 0m	DP	search mode on [start]	detecting	alert-close
3	system off [stop]	UA	search mode on [start]	off [stop]	closing down
4	User turns system on [start]	UA	Trigger from off to on [state change]	Boolean change off/on	its DEFINITELY on [start]
4	Continual search mode	CE	idle standby until somebody is found	no change	increased level of security
4	Victim is found	DP	Distance and victim 'located' [threshold]	Trigger event and distance	urgency
4	Victim is 0m away	DP	Distance and 'target reached' [threshold]	Trigger event and distance	Accomplishment
4	user turns system off [stop]	UA	shut down system	Boolean on/off	safe shut down [stop]
5	n/a	n/a	n/a	n/a	n/a
6	Continuous	CE	System is on and active [on]	n/a	practical functional
6	distance indicator	DP	system indicates current location [threshold]	pulse indicating progress towards or away [state change]	a pitch change to indicate distance [state change]
6	System ON [start]	UA	booting up	progression	n/a
6	System OFF [stop]	UA	shutting down	digression	n/a
6	Distance indicator	DP	system indicates current location [threshold-old/state change]	n/a	n/a

Table 8.1: Completed cue sheets participants 1-6, with highlighted text to mark event identification.

Part.	Identify Action/Event	Event Type	Desc./KW/Values	Behaviours	Themes/moods
7	System on <b>start</b>	UA	n/a	n/a	n/a
7	Search Mode on <b>start</b>	CE	n/a	n/a	n/a
7	Distance to Victim 10m	DP	n/a	n/a	n/a
7	Distance to Victim 0m	DP	n/a	n/a	n/a
7	System turned off <b>stop</b>	UA	n/a	n/a	n/a
8	turn system on <b>start</b>	SA o	n/a	n/a	n/a
8	continual search mode	CE	CE	n/a	standby
8	victim 10m away	DP	something found	recall attention	n/a
8	victim 0m away	n/a	n/a	n/a	n/a
9	Turn on the system <b>start</b>	UA	n/a	Rise	Good
9	Monitor the rescue	CE	searching	rise	good
9	Move to the victim	UA	n/a	Rise	Good
9	Report the distance <b>threshold</b>	SA	n/a	Rise	Good
9	Move to the victim	UA	n/a	Rise	Good
9	Report the distance <b>threshold</b>	SA	n/a	fall	Good
9	succeed in rescue	DP	n/a	Rise	Good
9	Turn off the system <b>stop</b>	UA	n/a	fall	Good
10	turn on <b>start</b>	UA	n/a	turn on <b>start</b>	n/a
10	listening	CE	n/a	conti event	n/a
10	warning <b>threshold</b>	DP	n/a	10	n/a
10	another warning <b>threshold</b>	DP	n/a	0	n/a
10	turn off <b>stop</b>	UA	n/a	turns off <b>stop</b>	n/a
11	user turns sys on <b>start</b>	UA	n/a	n/a	n/a
11	sys on <b>start</b>	CE	n/a	n/a	n/a
11	user turns sys off <b>stop</b>	UA	n/a	n/a	n/a
11	10m	DP	n/a	n/a	n/a
11	0m	DP	n/a	n/a	n/a
12	turn on <b>start</b>	UA	n/a	press a button	good
12	Search mode	CE	n/a	moving	good
12	getting closer	DP	n/a	moving	good
12	getting right position	DP	n/a	moving	good
12	getting further	DP	n/a	moving	good
12	turn off <b>stop</b>	UA	n/a	moving	good

Table 8.2: Completed cue sheets participants 7-12, with highlighted text to mark event identification.

**2b.**

Types of Events

start

stop

state change

threshold

	Time	Event	Assoc/ Cause	Description/value
E1	10.30	State Change	User Action	Coffee Break
E2	1pm	State Change	User Action	Lunch
E3	3.30pm	State Change	User Action	Coffee
E4	unknown	Threshold	System Action	more 10 people
E5	unknown	Threshold	Data Point	More than 70

The Cue Sheet helps us document the events and their timings within the scenario. This makes it a good document to refer back to at a later date. Particularly useful if the events are being moved around (see time-line) and you want to see the original layout, justification for design, thoughts etc or want to share ideas with other sound designers to interpret

Figure 8.1: The Cue Sheet.

threshold events and therefore it was decided that these will be used to classify and describe the events and also serve as examples to support the user.

A simplified cue sheet was created to support this version of SoundTrAD. The user, at this stage, was presented with a pre-filled out cue sheet as an example. See figure 8.1 for an illustration of what the user was presented with alongside the help text to explain how it serves to support SoundTrAD. The categories of the cue sheet are listed below and Figure 8.1 illustrates an example of a completed cue sheet.

- Time
- Event [state change, threshold, start, stop]
- Association/Cause (UA, SA, DP)
- Description/Value (qualitative or quantitative)

The SoundTrAD method was extended further, in order to provide direct support for data sonification. The option to map a set of numbers (a data set) was made available. The aim was to demonstrate how numbers can be mapped to pitch and how this can be done musically and with consideration of the other audio in the display. As a result, designers were supported in entering a limited set of numbers (10 numbers between 0-100) as part of the requirements gathering stage. See figure 8.2 for the interface they could use to enter numbers and the help text presented alongside.

This direct support for data sonification can be seen as a cartoonification of what might substantially be extended in future versions, both in terms of supporting additional methods of sonification beyond simple pitch-based parameter mapping,

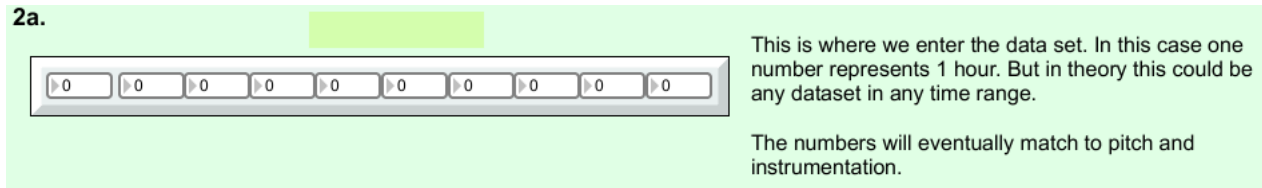


Figure 8.2: Entering the dataset.

and in terms of the quantity and number of channels of data to be sonified. What is intended here effectively is that this miniaturised support for sonification can act as a proof of concept regarding how sonification should be incorporated into SoundTrAD, and act as a place-holder for future possible extension of this functionality.

### 8.2.2 Mappings

The aim of the updates was to represent the potential of the database and principle behind the mapping. To demonstrate a set of mappings that draw on principles of soundtrack composition in order that integration of different sound types and aesthetics could be considered by the designer. The aim was that sound categories were made accessible and that it should be clear how the sound options related to the requirements of the AD. Listed below are the details of the mappings that were implemented at this stage:

- The dataset was mapped to pitch to create rhythm and melody. The designer could change the instrumentation and speed of playback in order to give a sense of control and change the rhythm. The data was mapped to the pitches of a major scale as inspired by Vickers and Alty (2002) who argued that tonal music should be preferred over direct mappings to frequencies. The numbers (0-10 = c/MIDI note 60, 11-20= d/MIDI note 62, 21-30, e/MIDI note 64, f/MIDI note 65, g/MIDI note 67, and so on through to MIDI note 72). In principle, these scaled numbers can be mapped to any major, minor scales and modes. The idea was that the data set is scaled to a western scale to create melody. There were 10 options for the instrumentation from drum to strings through to tuned percussion. A set of individual data points could be represented using music and can come together to create melody. See figure 8.3.

- Background: the designers were presented with 5 options from natural to musical (ambience to musical underscore [wind, sea, calm, electricity, strings]). It was decided not to represent status as a separate event (CE), due to the confusion it had caused. In order to enhance the display and perception of the data, as inspired by Hildebrandt and Rinderle-Ma (2013) who argued, convincingly that drones can be used to show lengths of processes, the aim was to map a continuous sound to a drone to clearly illustrate the length of the scenario. The parallel with soundtrack composition is that it can be used to establish place, enhance on-screen action, give sense of a size and create mood. The designers were told what to consider when picking their background sound: who the users are, where the display is heard and how it alters the perception of the events and data. See figure 8.4 for the interface and text that was presented to the designer.
- The events could be mapped to Foley/SFX or music. There were twelve options for the SFX and 7 for the motifs. Designers were told that these sounds can be used to represent everyday things or that if events do not have a real-world association, then motifs can be chosen as an option. The motifs were presented in the form of minor and major piano chords. In theory, this could be any chords or instrument, but the idea was that the sounds should be short and can be major (positive), minor (negative) or neutral. Motifs that have the same instrumentation, yet are altered in key helped narrate story and represent data points or events. To ensure the overall musical cohesion of the AD, (even if the user is not aware), it is necessary that the chords for the motifs, the melody for the dataset and the constant drone for background should all be associated with the same musical key.

## Tags

There were tagged suggestions (as examples) to help stimulate ideas and present analogies between the everyday events and sound effects. See figure 8.5 for the interface the designers could interact with and the help text. Listed below is an account of each option and the text of the help tag that could be accessed from hovering the mouse over the related image:



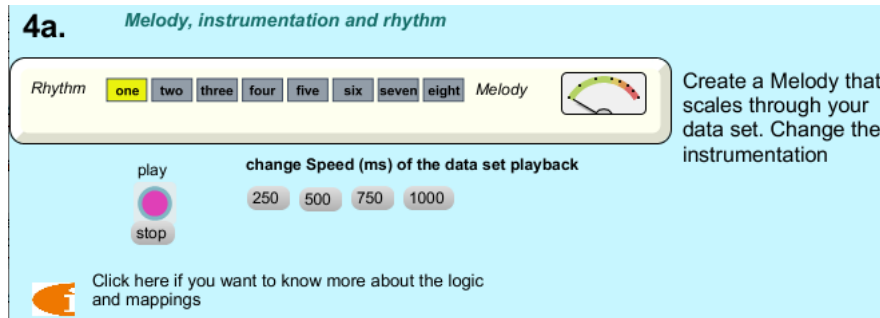


Figure 8.3: Entering a dataset to map to pitch/melody.

- sound/image 1: Hammer hit. Tag: “An action, a hit”
- sound/image 2: Breaking glass. Tag: “A break, a change, an error”
- sound/image 3: A spanner being turned. Tag: “An action, turn, change, position”
- sound/image 4: A door being shut. Tag: “An opening, closing, end, shut”
- sound /image 5: Letterbox. Tag “A delivery, arrival, message, sent”
- sound /image 6: Foot. Tag: “Process, Movement”
- sound/image 7: A bird. Tag: “An alert, a call, a message”
- sound/image 8: A bike pump. Tag: “A process, a movement, a decrease”
- sound/image 9: A boot on gravel. Tag: “Process, Movement, outdoors”
- sound/image 10: Jug being poured. Tag: “A state (full or empty), an activity”
- sound/image 11: Wave crashing. Tag: “A crash, a break, a change”
- sound/image 12: Light Switch. Tag: “On, off, change, switch”

### 8.2.3 Event Layout and the Timeline

The layout of the events on the timeline was not greatly altered from study three. However, colour coordination was used to relate the timeline to the volume control interface (see figures 8.6 and 8.7), where the first occurrence of any type of event was green, the second was pink and the third was blue. Of course, in principle there

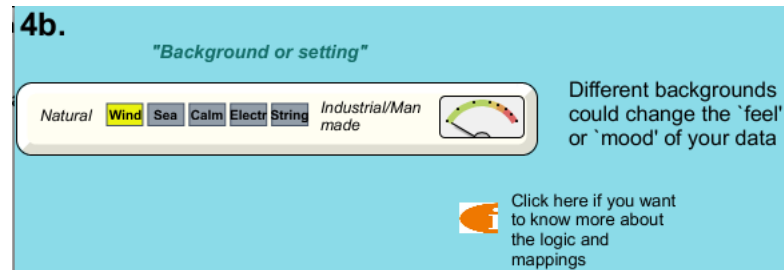


Figure 8.4: Background sounds.

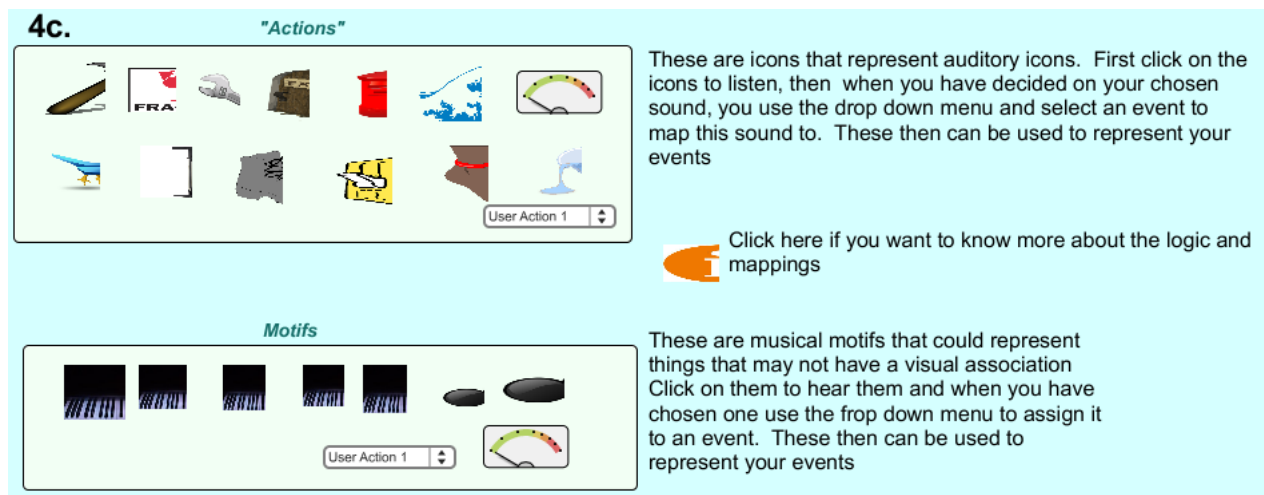


Figure 8.5: Foley and motifs.

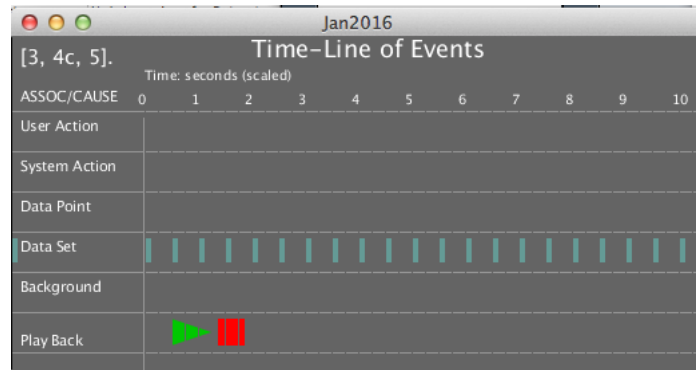


Figure 8.6: Timeline.

could be endless event occurrences and it is suggested, at this stage, that any new occurrence of an event be assigned a different colour or some identifiable feature in order that the user can link stages of the method and work iteratively, something highlighted in the findings of study three. Additionally, it is argued that this colour feature supports the comprehension of event layout, where it is possible that events can change order on the timeline.

#### 8.2.4 Other Features: Mixing the Audio

A control was provided to alter the levels of the events as they playback on the timeline (see figure 8.7). The objective was that the timeline tool could support an iterative design process as a result of providing the means to audition the sounds alongside monitoring and editing the final audio mix.

There were options to ‘turn off’ the dataset, individual events, data points or the background sound altogether. In theory, more detailed sound editing features could be added to the system, but at this stage, this is limited to volume in order to, not only show the power of this but also to provide a balance between giving users a sense of control without over complicating the user interface.

Additionally, it should be noted that it was felt that implementing full editing features would be an unnecessary attempt to ‘re-invent the wheel’. It is therefore suggested that any future implementation of the system could be used as a front end to established audio editing software.

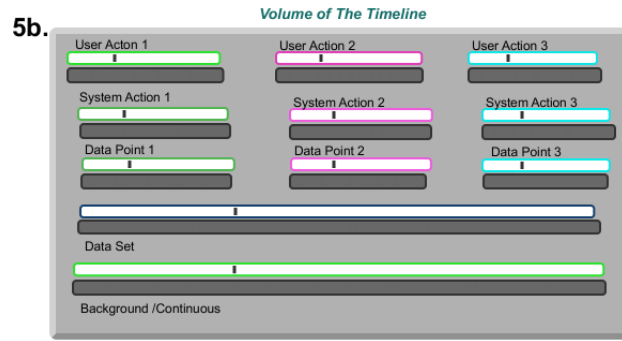


Figure 8.7: Change the playback levels of the events on the timeline.

## 8.3 The Evaluation

The goal of the evaluation was to assess whether the updates that were made to SoundTrAD, at this stage, supported the overall aims of SoundTrAD as a method and tool. Specifically, for this final study, this involved evaluating levels of confidence, enjoyability, usability, usefulness and the designer's ideas for future use and development.

The previous studies all highlighted that it was important to consider the study design in order that the potential of SoundTrAD was realised, despite the current implementation. It was concluded that it was vital to communicate through the study design that the system can be updated and serves as scaffolding. Specifically, that the database can be populated, the number of events increased and any scenario applied.

### Participants

Eleven participants took part in the evaluation and were from mixed backgrounds regarding their experience. Two participants (P2 and P6 ) had taken part in study two. Participants 1, 4, 6 and 7 had taken part in study three. The remaining six participants (P3, P5, P8, P9, P10 and P11) were all new to SoundTrAD. Participants were asked to rate their levels of experience in interaction design and music composition. Three had no experience of interaction design, one had a little, four had reasonable experience and three had a lot. Eight of the eleven participants had no experience of composing music and three had a little experience of composing music. The table 8.3 documents the level of experience of the eleven participants.

Part.	Interaction	Composition
1	Reasonable	A Little
2	Reasonable	None
3	Reasonable	A Little
4	A Lot	None
5	None	None
6	A Lot	None
7	A Lot	None
8	Reasonable	None
9	A Little	A Little
10	None	None
11	None	None

Table 8.3: Experience of interaction design and music composition.

## Tasks

The participants were presented with a series of tasks that supported them working through the system. A description of these can be seen in Appendix E. This description also contains screen shots of what the interfaces the participants used to enter the data and select sounds alongside the described task and optional information icon. If the information icon was clicked then this opened up a separate window. The content of each, outlining the further rationale behind the mapping options, is written in the Appendix E under ‘Information’. In summary, they were given 7 tasks that supported them creating an AD for one scenario. The final task permitted the participants to explore the ideas, change mappings and generally play around with their final creation.

## Data Gathering

Participants were presented with a questionnaire pre-study to gather their level of experience and rate their understanding of data sonification and auditory display (as outlined above). After the study, the participants were asked to complete the questionnaire by rating and giving their immediate feedback, regarding how they felt the system had supported their understanding of data sonification and auditory display post study. The goal was to compare the participant’s reactions before and after the study.

The participants were then sent a link to an on-line survey containing seven questions to gather ratings and open-ended responses regarding the usability, enjoyability and usefulness of the system. The survey also obtained information into whether the

Part.	AD (before)	Son.(before)	AD (after)	Son.(after)
1	Reasonable	A Little	A Little	A Lot
2	A Little	A Little	A Little	Reasonable
3	A Little	A Little	Reasonable	Reasonable
4	A Little	A Little	A Lot	A Lot
5	A Little	A Little	Reasonable	Reasonable
6	A Little	Reasonable	Reasonable	Reasonable
7	A Little	A Little	Reasonable	Reasonable
8	A Little	A Little	A Little/Reasonable	A Little/Reasonable
9	A Little	A Little	Reasonable	Reasonable
10	None	None	Reasonable	Reasonable
11	A Little	A Little	A Little	A Little

Table 8.4: Understanding of auditory display and sonification pre and post study.

participants would use SoundTrAD again and what scenarios they thought it could cater for. The questions and full open-ended responses are outlined in Appendix E. Included in the survey was the Brooke SUS scale. This was also used in studies two and three and is documented in Appendix B.

### 8.3.1 Findings

#### Study Questionnaire

##### *Question: Levels of experience and understanding*

Table 8.4 shows the participant ratings for their level of understanding of AD and sonification before and after the study. The ratings span from none, a little, a reasonable amount to a lot. One participant’s (P1) understanding of what an AD was, went down from reasonable to a little. Two participant’s (P2 and P11) understanding stayed the same at ‘A little’. Eight out of the eleven participants claimed their understanding of what an AD is had increased after the study with six responses changing from a little to reasonable, one response from a little to a lot and one from none to reasonable.

Nine out of the eleven participants claimed their understanding of what sonification is had increased after the study. Two (P1 and P4) had their understanding change from little to a lot, six from a little to reasonable, one (P10) from none to reasonable. One participant (P6) asserted that their understanding had stayed the same.

### Open-ended responses: how the system has supported their understanding

All eleven participants claimed in their comments that SoundTrAD could support an increase in an understanding of AD and/or sonification.

Being able to play around with the sounds helped their understanding, as illustrated by P9 when referring to the part of the evaluation where they could explore and audition their sound designs.

P9: *“Yes. It made it really straightforward and instructions were very clear. I particularly enjoyed the last task -7, section 5. I have lots of ideas now!”*

P5 felt that the instructions, tasks and system supported their understanding *“by explaining clearly what the remit was and then demonstrating, in an enjoyable way, how to create an auditory display and then play with it. It was simple, accessible, clear and well presented.”*

For P11, being able to *“build layers of sound”* helped their understanding, specifically how the audio could *“tell them things.”* Similarly, P3 felt it *“demonstrated the application of data sonification to a real-world scenario.”* P10 said that the *“system demonstrated how everyday actions/reactions could be communicated using audio”*, observing that *“this could have a huge amount of value to lots of scenarios. It felt rather easy to assign a particular sound to any given action/data point. As well as notifying what is going on, real time, it should also be really useful to review and identify trends, thus it could be a very effective planning tool (as well as monitoring tool).”*

According to P1 the method *“helped understanding and the tools illustrates the method clearly.”*

P2 felt that the system helped, arguing that the sound and music would be a *“pleasant way to listen to footfall”*, however, they felt that *“if they were relying on data to make decisions they would still prefer numbers and tables.”*

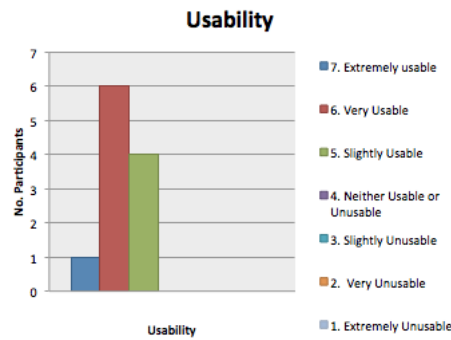


Figure 8.8: Q1. Usability rating.

### Questionnaire summary

The tools are beginning to support the method and clearly, playing around with sounds and having the means to interact with the data and the sounds during the design process, improve understanding. This could also be seen to relate to the enjoyability and usability of the method. The comment from P2 is something that was not expressed by other participants, however, it is worth considering how accurate the audio representations are.

### On-Line Survey

For full responses please see Appendix E, section E.2.

#### *Question 1: Usability*

Figure 8.8 shows that the lowest rated usability was 5 out of 7 with four of the eleven putting this, and the highest score from 1 participant was 7 out of 7 ‘extremely usable’. The mode was 6, ‘very usable’, with six out of the eleven participants claiming this. The mean score was 5.7 out of 7.

#### **Q1: OE responses**

The perceived usability of the system was related to how well participants felt it could cater for novice designers:

P5: *“Well explained and accessible without having much prior knowledge.”*



P7: *“Before this study, I have no idea of data sonification and audio display, not to mention creating it. This system gives me a very direct and efficient way to generate an audio display. Also, the system is intuitive to use.”*

Relating to this it was felt by P6, P9 and P10, the latter who was new to interaction design, that the step-by-step instructions and layout were clear. P6 added that the *“immediate feedback to user input also helped the usability.”*

This aspect of the system (being able to work with sound) gave a sense of control to the user. For example, P2 commented that *“It is nice to be able to change the volume of the sounds that are associated with the events. In this way, I can make important events more noticeable. In general, I feel in good control and able to change all the aspects of the sound.”*

It was felt by three participants, P1, P8 and P11 that the interface and screen layout inhibited usability. However, these three participants still found that the system made sense (P1), was quite intuitive (P8) or enjoyable once they had made the system work (P11). To exemplify:

P11: *“I’m a very visual person and understandably as a prototype, the presentation is quite crude but I could totally understand what to do, it was straightforward to use and I enjoyed playing with the data once I had made the system work.”*

**Summary of Question One:** The lowest usability rating of 5 out of 7 came from P1, P6, P8 and P11. P1, P8 and P11 all commented on issues with the interface and implementation as somewhat limiting its potential and usability. P6 liked the interface but compared it to the interface from the previous studies they have taken part in. Arguably, this could demonstrate an improvement in the system but there was further potential to develop it. Audio levels gave a sense of control (P2) and the instructions and layout were seen to be accessible.

## **Q2: SUS**

Figure 8.9 shows that there was a mean average of 78.6% with a standard deviation of 12.618. The highest was 97.5 and the lowest was 52.5.

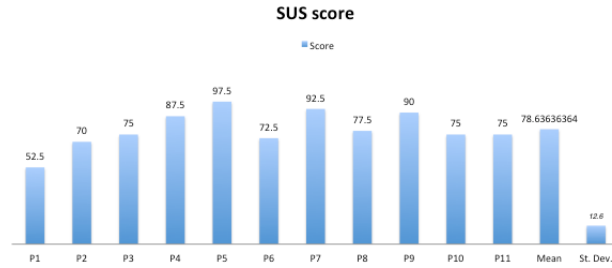


Figure 8.9: Q2. SUS Ratings.

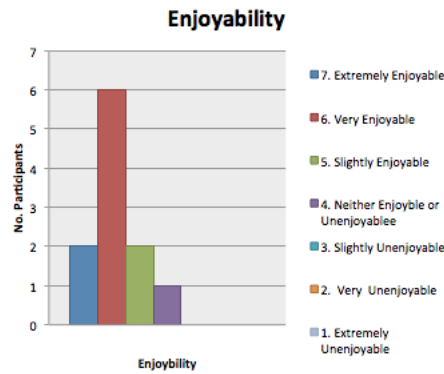


Figure 8.10: Q3. Enjoyability.

### Question 3: enjoyability.

Figure 8.10 shows that the lowest rated enjoyability score was 4 (neutral) from one participant and the highest was 7 out of 7 with two participants putting this. The mode was 6 out of 7 with 6 out of the eleven participants stating this. The mean score was 5.9 out of 7.

### Q3: OE responses

Enjoyability was related to the support of using audio during the design process (T2). It was found that it was *“enjoyable when [the participant could] listen to the sound and [could] actually tell what event is happening at the moment, listening to the track, modifying the various sounds, make(ing) it change sounds and frequency, good fun making beeps and playing around with it at the end,”* all supported high levels of enjoyability as described by P2, P4, P9, P8 and P11 respectively.

In relation to this, having the opportunity to create an outcome / display was also related to the enjoyability: P1 claimed it was *“nice to create a soundtrack to*

data” and P4 “liked listening to the ‘track’ [they were] creating through choosing and modifying the various sounds.” P5 stated that they were happy that [they could] could understand the system easily and then thoroughly enjoyed creating a display. It was fun.”

P8 said that they liked that there was “a nice brief learning curve from ‘what am I doing?’ to ‘oh, I see!’”. This was in contrast to P11, who enjoyed it once they had “learned how to use the system.” The participant further wrote that they “didn’t like the look of the system” and that “it appeared more complicated than it was in reality and better presentation would resolve this ‘gosh this looks complicated and wordy - will I understand this??’ feeling that [they] had when [they] initially looked at it.”

The sense of control and personalisation over the display also related to enjoyability. For example, P2 said that they liked to “design a personalised sound and actually listen to the sound [they] produced.” Arguing that “it is enjoyable when [they] listen to the sound and can actually tell what the event is happening at the moment (because [they] designed the sound).”

However, they found that there were too many steps to follow: “only wish there are less steps to follow to get what I want. Maybe you can provide more default settings when it’s actually in use.”

P2’s argument that they would like more default settings and fewer steps was contrasted by the view from P3, who wrote that they would have “liked to make use of more and different sounds, maybe inputting them [themselves].”

The layout and being able to visualise event layout also related to usability. P4 said they liked “the visual representation and seeing the playback in real time.”

P10 enjoyed considering the potential of the system and application areas.

*“I enjoyed thinking about all the various ways that this system could support/improve every day lives.”*

P7 enjoyed the “efficiency” of the system despite their “little knowledge” on data sonification.

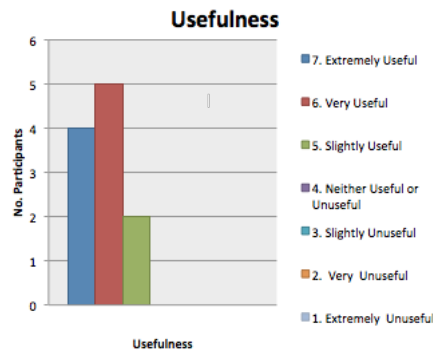


Figure 8.11: Q4. Usefulness.

### Q3: Summary.

The lowest enjoyability score was from P6 (neutral). P2 and P3 found it slightly enjoyable. They both thought there could be fewer steps, default settings (P2) and more user control (with an ability to input their own sounds). Enjoyability was clearly related to being able to listen to sounds and work with audio straight away (T2). The sense of personalisation and control also supported enjoyability as did being able to visualise the events and work with graphic representations.

### Question 4: usefulness for designing AD's for real world scenarios.

Figure 8.11 shows that the lowest rated usefulness was 5 out of 7, with 2 participants putting this and the highest 7 with 4 participants putting this. The mode was 6 out of 7 with 5 out of the 11 participants putting this. The mean score was 6.2 out of 7.

### Q4: OE responses

The perceived usefulness of the system for real auditory displays and sonification was down to its accessibility and simplicity (P5), ease of use of the interface (p6 and p7). P10 observed that *“Designing real auditory displays and sonifications is exactly what this system does.”*

Aesthetics was also related to usefulness as written by P2: *“The outcome represents the events well, and sounds pleasant.”*

The potential of the system and the possible applications were also referred to when describing the usefulness of the system and of the displays it can produce.

Importantly, the fact that it can be customised and adapted to a range of scenarios:

P4: *“I can see the potential of the system for scenarios as the one proposed as the example during the user test. It’s easily customisable for whatever use one has in mind.”*

P9: *“I would really like to use with historical data being archived on-line. I think this kind of audio display would be great for a variety of students needs and could make education more accessible for all. There are endless possibilities here I think.”*

Usefulness also related to the fact that users can develop ideas, as P7 observed. The *“system is very direct and easy to use. It’s like a concept sketch before any real displays.”*

It was also seen as useful for participants without an audio background. As P6 commented in regards to their own experience:

*“My specialism is not related to sound design but having tried features/options for sound manipulation of the interface I think the user will not only get their work done easily but also enjoy the ease of using the interface.”*

Once again, the interface was an issue for P11 who commented that they *“think the system as it is now as a prototype still makes [them] think that this could be worked on, adapted and used in real world scenarios.”* However, P11 concluded by writing that they *“think it’s a really usable tool.”*

P8 showed some confusion over the target users in relation to usefulness:

*“I don’t know :) Depends whether or not such a thing would be set up by the sound designer. In the example I played with I was pretending to be a supervisor setting the system to let me know when something was happening that I needed to attend to or be aware of -so I as an ‘end user’ might need more info about what it I was trying to achieve. Whereas if I was a sound designer using the system to create a bespoke auditory display for a client then its very useful.”*

#### Q4: summary

Two participants scored the usefulness as 5 out of 7 (P6 and P8), however, P6 gave positive comments when stating how useful they thought the system could be. P8 also showed some confusion regarding the target users. The usefulness was related to its usability but also clearly related to its potential and the wide range of scenarios it can be applied to. P9's observation about using it for historical data is specific and related to their specialism and so this reflects the potential for SoundTrAD to be adaptable and, as P4 stated, customisable to suit the users needs, (the designer/the end user).

#### *Question 5: Use again and any changes?*

Yes=54.55%(6)

Maybe=27.27%(3)

Do not know=9.09%(1)

Unlikely=9.09%(1)

#### Q5: OE responses

Five participants (P1, P4, P6, P8 and P11) argued that they could not really see or know whether they would need such a system, and as P1 said, *“they are not an AD composer.”* However, it was felt by the other 4 participants that if they did need to create an AD or sonify data they would use it. For example, P4 said they would *“definitely use it if [they] needed to monitor changes while also focusing on something else.”* P11, adding that they could, *“imagine that if [they] needed data sonifying then this is what [they would] would turn to. [They] can't think of any other systems that would do this.”* P8 said they would use it again and *“play around with it”* if it was *“freely available on the internet”*, but that *“sadly [they did not] have much call to create an auditory display.”*

There were also participants that felt that they would definitely use it again if there were changes. For example, P3 said that a change could *“allow the user to adapt it to their needs”* and P7 commented that *“if [they] use it again, [they] hope it could give [them] some suggestions when [they] assign the sound samples to the*

events.” Similarly, P10 thought they could “*use this system in a variety of ways*” but “*it would be better still if, when the user hovers over ‘user action’, ‘system action’ and ‘data point’, a brief explanation appeared.*”

There were also participants that would use it if it were developed or could be applied to specific needs:

P2: “*It’s nice to have a different way to perceive your data. I would like it more if the system makes real-time responses to the events. e.g. It would be nice to use the system along with a baby monitor with some sophisticated computer vision algorithms. If a baby wakes up, rolled over, or even fell off the bed the monitor can make a warning sound otherwise it makes nice music.*”

P9: “*I would like to find out more about how to adapt this for history teaching. Maybe if a programme could be designed to aid revision and as I really do think there is scope within the increasingly popular method of digitally archiving historical documents.*”

#### **Q5: Summary**

It is clear that most participants would use this again given changes or a specific need. P11 is a novice to interaction design and music composition and observed that they did not know of any other system that could do this. There are “*no commercially available systems in the everyday world.*” However, as has been outlined in chapter 2, there are systems but they do not offer the scope for a novice designer.

#### ***Question 6: Other scenarios.***

The responses demonstrate the wide-range of scenarios and applications that participants felt the system could be used for.

P1: “*sport events, data sonification, live data performance tool.*”

P2: “*I would like if it can respond to real-time events. Then it can be used in public areas such as cafeterias. The system can be related to the playlist the cafe is using. When there are more customers in the shop, play some pop music or music with a quick tempo, the customer might eat faster and leave quicker. When there are only*

*a few people in the cafe, play some classic music to ease the pressure of customers.”*

P3: *“analysis of any complex system e.g. scientific research.”*

P4: *“For tasks or cases that need constant monitoring and need to fire alerts if changes happen, while users are occupied doing something else. Almost like a background monitor.”*

P5: *“Petrol consumption. When client payments made to their bank account (might be too complex but would be really helpful) Metered water consumption. When I need coffee!”*

P6: *“I think it can be applied to use with any storyline/events that need auditory display. Not limited to only moving image or sound-based projects.”*

P7: *“Music education, an aiding system for sensory-impaired people, mobile application, animal monitoring, and so on.”*

P8: *“Transport hubs like railways stations and airports, either for people (queues building up, need more staff on check in desks etc) or for the logistics of moving bags (airports) or rolling stock (sending in more carriages) or even having an alert for a problem with trains and getting rail replacement buses.”*

P9: *“Digital archives. Revision aids. Teaching aids especially for students with special educational needs.”*

P10: *“To help workers ‘keep an ear’ on their work. To help supervisors monitor staff activity. To help managers review data and plan accordingly. To add auditory and notification to already existing IT systems (in vehicles/computers/classroom environments). Hugely beneficial to people with impairments.”*

P11: *“in vehicles for optimum performance and monitoring. For use in medical and sporting monitoring equipment. for monitoring energy use in the home/business. for use in extreme locations for monitoring yourself/the environment. to aid a person with disability/medical condition. For anyone that is multitasking any situation and needs to monitor and respond to situations while engaged in another activity”*

To summarise the possible applications:

Monitoring, Data review and trends, real-time scenarios, multitasking, alerts and alarms, sports, medicine, health, environment, performance, education, transport, special educational needs and business.



### Question 7: Any other comments.

There were no negative comments received for this question. P9 said it was “*impressive stuff*’.’ P10 commented that the system has “*endless potential*.” P7 suggested “adding more samples.” P4, P8 and P5 said they thought it was “*enjoyable*”, with P4 adding that it was “*easy to learn*.”

### 8.3.2 Summary of The Findings

The aim of this study was to explore how well the updates that were made to the event classifications and mappings and to the tools supported SoundTrAD. Specifically, the aim of the study was to explore how the method and tools integrated, as a system, and to gather reflections on usability, usefulness, enjoyability and further applications.

This version of SoundTrAD needed to show the potential of the method. Therefore, the study design had to communicate that the system can be updated and serve as a scaffold.

Out of usability, enjoyability and usefulness, it was the usefulness that received the highest average score of 6.2 out of 7, with the highest frequency of participants rating it as extremely useful. This was followed by enjoyability (average score of 5.9) and then usability (average score of 5.7). This outcome could reflect that the method potential was realised and despite some remaining issues with usability, it is clear that given full or professional development that it would be a useful system. The enjoyability was also an important part of the system in particular how this related to the use of audio throughout the design process. Particularly, iterating ideas, exploring options and subsequent potential aesthetics of the final display.

The realisation of the system potential of this version of SoundTrAD also feasibly means it can support novice designers while also catering for designers with more experience. Designers, who could in principle, update and add to the system within the given scaffolding.

The wide range of scenarios that it was proposed the system could support confirms that process monitoring is a good application area. Despite having one scenario to work with for this study, participants were able to think of a wide range of other scenarios and were not necessarily limited or influenced by the example they

worked on. Something that was not observed in previous studies.

In relation to the updates, the simplification of the cue sheet and requirements did not seem to limit creativity. It was found that participants did refer to the pre-filled out cue sheet when designing audio in order to match event types and description to sound ideas. Additionally, they also looked at it when considering the initial layout of the timeline. Every participant moved the events on the timeline and created a composition.

Participants spent a long time playing with their compositions and trying out different ideas and mappings. The choices of mappings were varied among participants, however, all participants went for the Foley/SFX when adding sounds to the user and system events on the timeline. It is hard to say whether the tags or visual icons helped in their choices and if there was a relation between this and the chosen sounds, as this was not observed directly. However, all participants auditioned the available options before making a selection. Every participant also altered the levels of their final mix once they had loaded the sounds onto the timeline.

## Chapter 9

# Discussion and Conclusions

This thesis provides a solution to bringing soundtrack composition to the creation of auditory displays and provides a systematic, empirical evaluation of that solution across a range of scenarios and levels of user experience. The thesis describes the investigation into whether a method and supporting tools, based on ideas from soundtrack composition and interface design, could be synthesised to support the structured development of auditory displays. The research was motivated by a proven lack of methods that support a novice designer in creating auditory displays (Frauenberger & Stockman, 2009; Brazil & Fernström, 2009).

The approach combines ideas from film soundtrack composition and traditional methods for interface design to offer a new method for the design of interactive auditory interfaces. The work documented in this thesis synthesises and evaluates this new approach. This new approach is independent of any specific technology. However, also presented in this thesis is the iterative development of a computer-based tool that supports and facilitates the use of the method.

The development of SoundTrAD presented a ‘wicked problem’, which led to the adoption of a research through design (RtD) approach as an underpinning research methodology for the project. The bringing together of the two disciplines of soundtrack composition and interface design into an approach to auditory display design represented an example of conceptual blending, the theory of which also was used to underpin the approach taken.

The project started off with a research question: what can soundtrack composition bring to the design of auditory displays? This question led to an examination of

the parallels and differences between the two disciplines, and a conceptual blending which formed the basis of a new method for AD development, which was subsequently refined using an RtD approach.

Specifically, the development of SoundTrAD started with the identification of a set of research objectives, which are outlined in chapter 1 and restated below. Included in this was the objective to iteratively design and develop SoundTrAD, placing emphasis on features that it could provide and what it aimed to support as a method for the design of auditory displays.

- Literature search and analytical comparison: compare the disciplines of sound-track composition and interface design. Take inspiration from conceptual blending. Look for parallels and differences between the two disciplines with the aim to propose a unique perspective on how to develop SoundTrAD.
- Devise and refine methodology: identify a position and approach and the research methods that will be used to investigate, design and evaluate SoundTrAD (within the overarching RtD methodology).
- Design SoundTrAD: synthesise versions of SoundTrAD, evaluate them and iterate this process. To focus specifically on features that SoundTrAD will provide and what it will support as a method, including:
  - Capturing the different perspectives of AD designs such as the display's behaviour over time and the event to sound mapping.
  - Capturing the rationale underpinning design decisions.
  - Supporting the iterative refinement of AD designs.
  - Enabling the early prototyping of sounds.
  - Accessibility and support for novice auditory display designers.
  - Computer-based tool support for the method.
- Evaluate a final version of SoundTrAD with the target user-group. Identify further design potential, in order to stay true to the research through design approach and explore further levels of detail/features of both contributing disciplines suitable for further conceptual blending.

Therefore, the research described in this thesis took an RtD approach, and was in turn informed by ideas from conceptual blending in relation to the bringing together of the two contributing disciplines to form a new space for AD design. The objectives described above provided the specific steps that were taken to realise and refine the method and tool, underpinned by the RtD approach.

Specific detail of the work that was carried out is documented next in section 9.1, which starts by discussing the theories and methodologies that were used to carry out the research. Following this, the chapter discusses each study before outlining the contributions of the research in section 9.2.

## 9.1 Approaches, The Studies and The Findings

### Research Through Design

In order to iteratively develop SoundTrAD research through design (RtD) was utilised as a suitable underpinning methodology. RtD is seen as a methodology suitable to address ‘wicked problems’ or ‘messy situations’ (Zimmerman et al., 2010). These have been identified as design problems that are not suitable for conventional scientific exploration. RtD lends itself to addressing these problems because it aims to integrate knowledge and theories from across multiple disciplines in a holistic way. Therefore, it was felt that the ‘messy’ or ‘wicked’ problem of bringing together soundtrack composition and interface design could be supported from using an RTD approach. Consequently, the development of SoundTrAD was exploratory and iterative. Each study aimed to design and develop SoundTrAD further whilst taking on findings from the study that had preceded it. As a result, and even though as mentioned, the research objectives were used to shape the project, there remained an important element of exploration that characterised the project.

One feature of RtD is the principle that a set of artefacts can be designed in order to address the problem and provide discourse around the research being carried out (Zimmerman et al., 2007). Once several artefacts have been designed, then the project can take on more traditional research methods. For the development of SoundTrAD then, it is argued here, that this constitutes the refining of the method steps and the development of the computer-based tool. Therefore, the methods

employed at later stages in the development of SoundTrAD were more traditional. For example, studies three and four both used more conventional HCI evaluation methods.

## **Conceptual Blending**

In order to develop SoundTrAD this project addressed the bringing together of soundtrack composition and interface design. The theory of conceptual blending was drawn upon to address this ‘problem’, in so far as it supports exploration into how two or more disciplines can combine to form a ‘blended space’ (Fauconnier & Turner, 2003b).

It was felt that a blended space, where elements of soundtrack composition and interface development come together, could inspire a framework for the SoundTrAD method, and so research was carried out into the similarities and differences between the two disciplines. This resulted in early ideas for the method stages and steps for SoundTrAD (see figure 3.3 in chapter 3). The stages were based on established design stages for interface design: requirements gathering, conceptual design, detailed design and evaluation. The steps that were proposed to reside within these larger stages also drew on identified parallels between AD design and soundtrack composition (see table 3.1).

Differences between the two disciplines were also identified (see section 3.4.2), for example, the fact that auditory display design needs to cater for the potential non-linearity of user-interaction, whereas soundtrack composition tends to utilise a linear narrative. Additionally, soundtrack composition places importance on the integration of many different types of sounds and the aesthetic of the final soundtrack. The design of auditory display does not place such emphasis on how audio within the display can combine and formulate an integral whole. As a result of these findings, it was proposed that SoundTrAD should aim to support the designer in considering the integration and aesthetics of any sounds and how the potential ordering of interaction events can effect this. This lead to an updating of the list of features that SoundTrAD should aim to support as a method in order to include considerations (see section 3.5 in chapter 3).

### **9.1.1 The Studies**

#### **Chapter 4**

Study one explored the use of scenarios for the design of auditory displays (Benyon & Macaulay, 2002; Benyon, 2010; Diaper & Stanton, 2004). Specifically, stories of hypothetical users interacting with an AD. The study developed the idea of using a cue sheet as a technique to help the designer map out events from a given scenario, by identifying actions, objects and subsequent ideas for sound. See figure 4.1. It was concluded that whilst the cue sheet did fundamentally provide an organising mechanism for laying out events within a scenario, it still needed clarifying and that users could benefit from understanding more about the aims and context of its use. This outcome supported ideas for further development of SoundTrAD version 2.

#### **Chapter 5**

Ideas for updates to SoundTrAD were generated from the findings of study one. The goals were to further support the designer in the requirements gathering stage of the method and begin to investigate how requirements can map to sound. The method stage for requirements gathering, therefore, was updated to support the designer in analysing the information that needed to be sonified. This involved the designer identifying properties and characteristics of the information events that needed sonifying. Following this, a database of ideas was started based on how sound is treated and used in film and the ways that composers would spot a scene when creating a soundtrack (Sonnenschein, 2001). Ideas for the database came from the soundtrack literature, namely Beauchamp (2005); Lipscomb and Tolchinsky (2005); Collins (2009) and can be explored in section 5.4 of the thesis. In its early stages, the database was designed with the intentions of supporting an iterative approach to design (through the designer having the ability to audition sounds early in the design process).

#### **Chapter 6**

At this stage in the research, the cue sheet itself was programmed in order to support usability. Additionally, a basic timeline was created. The sound ideas and

suggestions were placed on the timeline in order to start to consider event layout in the scenario, a subsequent visualisation of the ordering of events and sounds in the interface and the final design itself. A user study was performed of this early stage design to explore the validity of the approach taken and to gather early reactions from participants (in line with the RtD approach).

The idea was to involve participants with experience in designing interfaces in order to inform the design and obtain expert feedback. A think-aloud session supported this objective.

The responses were analysed using thematic analysis (Braun & Clarke, 2006), in order to gain a deep insight into any issues and themes surrounding the overall aims of SoundTrAD and how well the updates and developments supported these. The study resulted in a refined set of themes that were used to underpin ideas for further development (see section 6.4). These included ways that a designer can be further supported in their creativity and the usability of the method (using audio in the design process-T2). The themes also identified ideas for simplifying and clarifying the terminology (in order to make SoundTrAD more accessible-T3) and development of the timeline and cue sheet as supportive tools (namely the usability of their interfaces-T4).

## **Chapter 7**

These user-informed developments were implemented for another user study (study three). This involved developments to support less restriction on the requirements and development of an event ontology as inspired by Dix et al. (2007) and (Brewster & Wright, 1995), that could be used to help classify the information in order that the user would feel less constrained in their choices. However, it was also important to support the design and not let the users feel overwhelmed: a trade-off that had emerged between creativity and support and was identified as a recurring theme (T1).

The cue sheet was designed to be simpler to use and support free text entry. Audio was used earlier in the method stages. For example, the user was supported in navigating a database of sound ideas at any stage during their design and could audition sounds when it suited them in order to support an iterative and integrative



way of working. The timeline was also updated and designed to support an interactive approach to designing the display. The user could move events about on the timeline and start to think about the mapping stage of the design in more detail. For example, they could audition sounds, check for masking and begin to hear an early prototype of their display. Finally, the database of sound examples was populated with 80 sound samples and supported navigation in relation to the requirements, sound types or soundtrack composition categories. It was intended that this could support access from multiple perspectives and simplified terminology.

The user study showed that SoundTrAD was starting to assist the user in designing auditory displays. The study showed an increase in usability and evidence that the timeline benefited and supported the design process. For example, the SUS increased from 67.2 (out of 100) in study two, to 71.9 in this study three. Additionally, six out of the twelve participants for this study felt that their design ‘completely benefited’ from the timeline (see figure 7.11).

However, there were still a few issues around the terminology, event classifications and the user’s sense of feeling in control or confident in using SoundTrAD. To exemplify this, only two out of the twelve participants felt ‘extremely confident’ using SoundTrAD. Despite this, 50% of participants still felt confident (rating it 7 out of 9) and only one participant rated their confidence as 3 out of 9. This highlighted the range in confidence that participants felt when using SoundTrAD. There were also issues around the sound choices. It was felt by the majority of participants that they would like more choices, while one participant argued for having less. What was clear was that guidance could have been provided in selecting and navigating the available sounds. It was therefore concluded that the system should support an approach that communicates the potential for adding further sounds and mappings: the idea that the designer would feel confident adding, developing and asking for sounds in the future and not feel limited by the scope of the tool and what specific sounds it happens to contain.

## **Chapter 8**

For the final user study the goal was to target novice designers, as an important part of the rationale for SoundTrAD is to make AD design more tractable to users with

little or no interface design experience. To do this, a number of things were done to simplify the method and supporting tool from the version used in study three. The final user study four saw restrictions on the parameters and audio choices. For example, the users were presented with a filled out cue sheet, demonstrating the different events and how they could be used within the scenario. Alongside this the available sound choices were limited. However, the aim was to make it clear that these were examples and that they can be updated within the suggested parameters and had the scope to be adapted, enlarged and personalised.

Fundamentally, the aim was to support the designer and their levels of confidence but also lower the potential for them to feel overwhelmed, restricted or confused. Audio was used early in the design process and at every stage of the method, the interfaces to the tool was adapted to be more usable and the terminology (event classification) was simplified.

The cue sheet was filled out with an example that the users could work from. This was based on a hypothetical scenario and using event classification that were influenced by Hildebrandt and Rinderle-Ma (2013) and their use of events for process monitoring. The timeline was re-programmed to address issues with usability, the database was presented as a series of SFX, musical motifs, background sounds and pitches (that mapped directly to user entered numbers) in order to support the integration of the different stages of the method. It was the intention that it would be possible for users to build a display and understand how different types of sounds can be combined to communicate the information from the AD and how sounds could be combined to present a holistic, integrated and functional auditory display.

The user study was carried out to gather the perceived usability, usefulness, enjoyability and further ideas for SoundTrAD. The results were largely very positive. As a result, SoundTrAD version 4 was shown to lower the barriers to AD design and support an increased understanding of what an AD can be used for. It was also demonstrated that the cue sheet provided a good mechanism for capturing design rationale at the point of design creation. Importantly, the method was understood to have potential and its principle aims and approach were clearly understood. As a result, ideas for future work were easy to identify.

### 9.1.2 A Reflection on The Methods Used

#### *Research Through Design*

Documented below is a set of criteria that Zimmerman et al. (2007) proposed for using RtD: ‘Process, Invention, Relevance’ and ‘Extensibility.’

As such, they are used here to enable critical reflection concerning how the RtD methodology was used in the development of this research and the outcomes that were produced as a result.

##### **Criteria: Process**

The research and development process must be documented so it is reproducible. Importantly, Zimmerman highlights that even though outcomes could be different, the rationale should be provided for the choice of methods that are used.

##### **Outcomes**

This thesis has documented the research methods used for each stage of the process of the development of the SoundTrAD method and supporting tool, and given rationale for the choice of the methods used. Regarding reproducibility, somebody else pursuing this research question would not be likely to come up with the same method and tool as described here, but using the thesis, they would be able to understand how the approach that was taken which led to the development of the specific method and supporting tool.

##### **Criteria: Invention**

By proving that a novel integration of various subject matters to address a specific situation has been produced. Done by an extensive literature review and a demonstration of how advances in technology could result in significant advancement. The articulation of this invention is how the detail of the technical opportunities is communicated to the engineers, providing them with guidance on what to build.

##### **Outcomes**

This research has produced a novel integration of soundtrack composition and interface design to produce a new space for AD design, guided by the theory of conceptual blending. The need for such a space is documented by (Frauenberger & Stockman, 2009) and (Barrass & Frauenberger, 2009). There is no evidence of anything similar reported in the research literature. The method itself is technology neutral, but the

various diagrammatic and textual descriptions of the method and supporting tool would enable an engineer to realise the approach on a range of platforms, including mobile and on the web.

#### **Criteria: Relevance**

This represents a shift from traditional ideas of validity in scientific research. The designer must communicate the preferred state their design attempts to achieve and provide support for why the community should consider this.

#### **Outcomes**

There is a growth in the use of mobile technology and multimodal systems and, consequently, the need for a deeper understanding of the value of auditory displays within this context (Frauenberger & Stockman, 2009; Brazil & Fernström, 2009). Therefore, a method and tool to support the creation of ADs is highly relevant to the developing technology landscape and worthy of consideration by the HCI community.

#### **Criteria: Extensibility**

This is reflected in the ability to build on the contribution. Either applying the process in a future design problem or understanding and leveraging the knowledge created by the resulting artefacts.

#### **Outcomes**

Currently the method and tool have been explored predominantly in relation to process monitoring applications. However, the method itself and the supporting tool could be extended specifically to address additional application domains within this area, specifically for example the Internet of Things and medical monitoring systems. Extensions could be developed to all of the components embodied by the tool, but particularly the database could be developed and extended both in terms of the number of sounds and sound categories it supports, and the different views and navigation approaches made available to users.

The research documented here meets all of the above criteria, demonstrating that, not only was RtD a suitable method to apply, but it also enabled a set of outcomes and contributions to be identified from the research.

Study	Score	St. Dev.
2	67.2	21.2
3	71.9	16.6
4	78.6	12.6

Table 9.1: Usability (SUS) for Studies 2, 3 and 4

Study	Usability	Usefulness	Enjoyability	Other
Study 1	Cue Sheet: context, number of events identified and verbal feedback	Verbal feedback and types of audio identified to inform later designs of database	n/a	n/a
Study 2	SUS, think-aloud, thematic analysis in relation to method and tool updates	Think-aloud, thematic analysis in relation to method and tool updates. Comments on further scenarios	Think-aloud, thematic analysis in relation to method and tool updates	Think-aloud, thematic analysis in relation to other aims of the method: target users, aesthetics, integration and iteration
Study 3	SUS, rating and OE about interfaces to the tools, number of events compared between timeline and cue sheet	Rating and OE about method steps, cue sheet (requirements) timeline and database	n/a	OE further applications/scenarios, rating for confidence
Study 4	SUS, rating and OE to gather usability of the system as a whole	Rating and OE to gather usefulness of system as a whole	Rating and OE to gather enjoyability of the system as a whole	OE-further scenarios. Rating and OE to explore increased understanding of sonification and AD

Table 9.2: Study Comparisons. What was being evaluated in each study.

## Qualitative and Quantitative Research Methodologies

All studies facilitated an understanding of the perceived usability and usefulness of SoundTrAD. They also gained insight into whether the participant would use it again and what ideas they had for future applications and developments. The success of the iterative approach was effectively demonstrated with the increased usability, as measured by the SUS scale (Brooke, 1996). The scores of which can be seen in table 9.1. Table 9.2 outlines the type of evaluation that each study employed and what techniques they used to explore usability, usefulness, enjoyability and gain feedback for further design ideas.

The SUS score increased with each study, with the standard deviation decreasing. This demonstrates increased usability on average with each version of SoundTrAD that was evaluated using this scale. This also shows that the range in responses diminished as SoundTrAD was developed. That is, the range decreased between those participants that found it usable and those that did not. The other measure of usability included obtaining the number of events participants identified (study

one), talk-aloud and TA (study two), rating scales and open-ended written feedback for the tools (study three) and rating scales and open-ended written feedback for the system as a whole (study four).

Due to the range of measures, it is not as helpful to compare scores or findings between the studies directly. The same applies to the measures that were used to obtain the usefulness and enjoyability of SoundTrAD. Once again, a direct comparison has little value due to the different techniques that were used. For example, study two used think aloud and TA, study three used a 9-point rating scale and also asked for usefulness regarding not only the method as a whole but for specific features of SoundTrAD, and study four used a 7-point rating scale, with semantic tags and asked about the system as a whole.

It was clear from the open-ended responses that the number of negative comments decreased and, overall, users were more positive about the final implementation and potential of SoundTrAD. This loss of the ability to compare some of the results obtained across studies was felt to be a worthwhile sacrifice in order to employ research methods and techniques appropriate to each of the stages of the development of SoundTrAD.

## 9.2 Contributions

Below is a list of the contributions resulting from the work reported in this thesis.

- The synthesis of a novel approach to the design of auditory interfaces, including:
  - The identification of a set of parallels between AD/interface design and soundtrack composition (table 3.1).
  - A synthesised set of method stages and steps for SoundTrAD based on similarities and differences between the two disciplines (see figure 3.3).
  - The unique bringing together of the theory of conceptual blending and a RtD methodology to design and develop SoundTrAD.
  - A prototype computer-based tool that has been used to support and facilitate the SoundTrAD method.

1. A cue sheet to support requirements gathering and the capture of design rationale. A means for a designer to enter a dataset and to use subjective qualitative and quantitative descriptions to design events. See figure 8.1.
2. An interactive timeline to enable auditioning, arranging of events and support working with use-case scenarios. See figure 8.6.
3. An early stage database of mappings from soundtrack composition to interface requirements. See section 5.4.1.

### **9.2.1 More on The Current Prototype and Computer-Based Tool**

Another distinct contribution is the portfolio of components that have been implemented during the development of SoundTrAD.

This contribution is, therefore, made in the form of a series of recommendations for how to further implement computer-supported versions of SoundTrAD.

A version of each of these components has been implemented and evaluated during the process of developing the SoundTrAD, in some cases in more than one of the studies. One can envisage a range of implementation alternatives, varying widely in the number of options and level of support provided. Detail is provided below on how the computer-based tool has evolved through the research and where they stand to-date. This is followed by set of implementation recommendations (IR) that draw on evidence and feedback from the four user studies.

### **The Development of the Tool and its components**

The results of the final study four indicate that novice designers are best supported through the implementation of a relatively cut-down version of the tool which contain examples and tags in order to support highly iterative working and the early auditioning of sounds.

The results also go some way to show that if a more experienced designer were to employ SoundTrAD, they could do so and not feel restricted by the cut down parameters. Thus addressing the recurring theme (T1); the trade-off between support and creativity. For example, study three utilised a cue sheet where free text could be entered in order that qualitative, individual suggestions for events and sound ideas

could be documented.

However, the cue sheet also supported the selection of a limited number of events (UA, SA, DP and CE). It was successfully demonstrated that the selection of these was similar between participants. As a result, the cue sheet was shown study three to assist the designer whilst also not limiting their descriptive and personalised documentation of the events.

Study four utilised this knowledge and incorporated an example cue sheet into its design. The example cue sheet was based on the completed cue sheets from study three. This served to demonstrate the role of the cue sheet in a simplified way to the novice designers of study four and for speed of use, giving users more time to explore the sounds and potential mapping options. The study showed that it successfully illustrated the place the cue sheet has in SoundTrAD as a documentation and reference point during the design process.

To stay true to the method, it is strongly recommended that any implementation must retain elements of all 3 major techniques, the cue sheet, timeline and a database of sounds. The database of sounds should be open to facilitate the addition of sounds by an individual designer, as well as the bulk import or referencing of whole libraries of sounds from other sources.

## Implementation Recommendations

Listed below are implementation recommendations (IRs) based on the findings from the evaluated computer-based tool and components of SoundTrAD from studies one to four.

- IR1: **The end user:** should be able to enter numbers (a data set) and reference events on the cue sheet with the option of selecting UA, SA or DP. The end-user should be able to enter personalised, notated ideas for the role of each event, design their background, map their data to melody and iteratively create their own display for the scenario relating to wherever it is this system is installed. From the end user's point-of-view: should be able to consider their context when creating the display, the activities and data they are sonifying and how the sounds work together.
- IR2: The implementation should support SFX/Foley, drones/ambience and



background, a scaling of number parameters to pitch within set scales (minor, major) and a set of motifs based on these scales. Rhythmic to melodic mapping, from tuned percussion to 12-tone melodic instruments. The background needs to reflect industrial to organic environmental sounds, or there needs to be clear definable scales that the end-user can select from. Additionally, harmonies and rhythms need to coordinate. These guidelines were used in the final implementation of SoundTrAD version 4. They are general enough but also address early proposed parallels between soundtrack composition and AD (see the database in chapter 5, section 5.4) and ideas that have been proposed throughout the thesis. These include the focus on the association between concrete auditory representations such as sound effects and auditory icons to represent events. This also includes the parallel between the use of earcons and the idea of a motif to represent occurring events, in relation to the suggestion that musical melodies and ideas from western harmony be used to build these motifs and represent the events. Additionally, this includes the idea that these motifs should alter in melody, pitch, harmony and instrumentation in order to represent events. In general, the concept that musical constructs benefit and can be layered alongside everyday sounds and ambient background sounds. This can be constructed and layered to build a soundtrack that users can customise when mapping. The guidelines that were used in study four from Hildebrandt and Rinderle-Ma (2013), can be referenced in chapter 8, section 8.1.

- IR3: The implementation should support a means to enhance the interface with icons, cue sheet to layout events and simple drag, drop timeline and text entry fields for the cue sheet and data sets. The user studies in the thesis have resulted in useful ideas regarding practical implementations of the interfaces. The ideas include the use of colour to coordinate the different stages of the method and support an iterative design process, the possibility to resize and move interface windows and the use of tags when hovering a mouse over certain icons and events in order to reveal more information regarding their role (see the open end responses for question 6b in chapter 7 and question 5 in chapter 8).

### 9.2.2 Limitations

The research presented here details four user studies. It would have been beneficial to have had more participants. This could have been especially advantageous for the final study where comparing novices with non-novice designers would have been useful to fully understand the impact of SoundTrAD and to refine an answer to questions around target end-users. However, this is something that can be addressed with further studies. It was beyond the scope of the thesis to implement a full-blown system, and it is only possible to provide recommendations at this stage.

As table 9.2 highlights, the evaluation methods were refined throughout the thesis, consistency within the studies in relation to what they were evaluating and how they did it, would have been advantageous. However, the approaches have presented the start of a body of scenarios, testing and applying SoundTrAD to real-world contexts. As a result, research methods, particularly those related to user-centred design and exploring the use of technology in context (Droumeva & McGregor, 2012; Hug, 2009) could certainly be used to inspire a suitable approach for further evaluations.

## 9.3 Future Work

**Who are The Target End-Users?** Study four demonstrated that novice designers can use SoundTrAD. However, it is fair to conclude that users with experience could also use SoundTrAD in regard to the fact that it can be updated, added to and expanded.

In terms of the role of the user, the end-users could be the designers, designing for other end-users (for example an interface specialist designing a product for a client using a given use-case), or the user could be designing an AD for themselves. A scenario to exemplify this could be where the driver of a car, for example, programmed their own personal display based on a set of their own actions. They could map their driving actions to events and subsequently hear how the display might sound and importantly, understand how their own context and actions affect the sound. It could, in fact, go a step further (given a future further development) and the driving actions of the user could affect the sound and playback in real time.

However, what remains important is the ability that the driver had to program and map out their scenario beforehand on the cue sheet. They could be able to audition and test different combinations of events and possible orderings of actions using the cue sheet and the timeline in relation to one another.

**What kind of scenarios can SoundTrAD cater for?** Throughout the thesis participants recommended possible further scenarios for SoundTrAD. Taking inspiration from all the scenarios suggested by users, it therefore could be advantageous to explore how other systems/methods and tools have designed for specific scenarios. For example, participant 11 in the final study thought that SoundTrAD could be used for health monitoring. So work by Baier et al. (2007), as just one example, could be used to inspire developments. Participant 8 felt it could be good for transport, so research by McGregor, Larsson, and Turner (2011) or Hansen and Bresin (2012) could help inspire ways that SoundTrAD might suit this. The list from participants was long (see section 8.3.1, question 6 from study four) and so it is fair to conclude that SoundTrAD has “endless potential” (P10, study 4) when it comes to possible applications. What remains important is the maintenance of the design principles and recommendations that were outlined in section 9.2 above.

# Appendix A

## Cue Sheets from Study 1

### A.1 Example for Study

#### **Example**

In this scenario an artist is using an application on her computer to render film footage. Due to the crowded nature of her screen she prefers to monitor the progress of the rendering through audio feedback, as opposed to checking it visually, due to the screen space this takes up.

*Sarah is a 39-year old visual artist. It is Wednesday afternoon and she is working at home in her central London flat. Sitting at her desk near the window she launches the film editing software on her computer and reloads the last project she was working on. She wants to review the work she did earlier that day which includes footage of an interview. In order to not waste time she decides to start the rendering process of a different scene whilst watching it. Once she has opened up the scene she wants to render, she clicks on the file tab and selects render from the drop down menu. She then goes back to the work she did this morning to review it carefully. After 10 minutes she hears the familiar sound that indicates that the rendering process has slowed down due to the particularly large image. After another minute she hears the familiar sound that indicates that the rendering process has sped up, before hearing the sound to indicate the process has completed.*

Figure A.1: Example scenario. Study 1.

### A.2 Cue Sheet From Participant 3.

Figure A.4 shows an example of a filled out cue sheet.

<i>Time and Place</i>	<i>Actions</i>	<i>Objects</i>	<i>Attributes and Descriptions.</i> <i>What do you know about the action or object? For example, Does the action or object have a size, quantity or type? Is there a location in which the action or object happen/exist in?</i>	<i>Do you associate a sound with this (Yes or No)</i>	<i>Causes of sound and what the sound may be</i>	<i>Type of sound: Music, speech, sound effects, other?</i>
Wednesday	Working	Home	Afternoon	Yes	Traffic outside of window. Car engines	Sound effects
	Working	(Home)	(Home) Central London	Yes	Neighbours	Sound effects / speech
	Sitting	Desk		Yes	Creaking chair	Sound effects
		Window	Near desk	No		
	Launches	Film editing software	Computer	Yes	<del>Woosh</del> sound as opens	Music / Sound effects
	Re-loads	Last project	Working on	No		
	Review	Work	Footage of an interview	Yes	Sound of interview	Speech
Day			Earlier	No		
	Start Rendering process	Rendering process	Different scene	No		
	Opened up	Scene	'Wants to render'	No		
	Clicks	File tab		Yes	Click of mouse button	Sound effects
	Selects	Render	Drop down menu	No		
	Goes back	Work		No		
		Review	Carefully	No		
	Heard	Sound	Rendering process Slowed down due to large image	Yes	(this is up to designer)	Music / Sound effects
	Hears	Sound	Familiar, rendering process has sped up	Yes		Sound effects
	Hears	Sound	Process has completed	Yes		Sound effects

Figure A.2: Example Of A Completed Cue Sheet. Study 1.

### A.3 Sound Design Choices

Tables A.1 and A.2 highlight the event and sound design choices for all 7 participants.

Participant	AD	Cause	What sound maybe	Type	Category
1 (initial pilot)	indicated track moved from track number 1	Digital	Digital	N/A	SFX
	indicated reached track 6	Digital	Digital.	N/A	SFX
2 (initial pilot)	Pushed joystick	Audio indication	Audio indication	N/A	SFX (?)
	indicated track moved from track number 1	Audio indication	Beep (track 1)	N/A	SFX
	indicated reached track 6	Audio indication	6 beeps (track 6)	N/A	SFX
3	Track changing	iPod	abrupt shift in music	musical	music
4	change track using joystick	MP3 player	auditory display	informative speech	speech
	Pushed joystick	joystick mechanism	mechanical	click	SFX
	changing track	MP3 player	auditory display	informative speech	speech
	joystick	joystick mechanism	mechanical	click	SFX
5	changing track	track changing	tick, music	music, digital sound	music/SFX
6	Pushed joystick	joystick moving	whirling sound	digital	SFX
	indicated reached track 6	joystick selection	speech of track number	organic	speech
	indicated track changed	joystick selection	speech of track number	organic	speech
	Release of joystick	joystick pressure removed	distinctive unique set of beeps or ring	organic	speech
	Joystick in neutral position	joystick not activated	a dinger reassuring that disengaged	digital	SFX
7	Using joystick to change track	iPod click	track changing specific to iPod	Electronic	SFX

Table A.1: Scenario 1. Participant sound choices and categorisations for the ADs.

AD	Participant	Cause	What sound maybe	Type	Category
1 (initial pilot)	Turns on PC	PC firing up	PC firing up	Related to software on PC/Mac	SFX
	Launches email app.	email app	letter falling into mail box.	N/A	SFX
	Email arriving	Email app.	A bell	N/A	SFX
	Email specific to wife	A woman's voice	A "hello"	N/A	speech/SFX
2 (initial pilot)	Turns on PC	Branded Digital Noise BDN	BDN	SFX	SFX
	Launches email app.	BDN	BDN	N/A	SFX
	Indicator of Email being opened	BDN	BDN	N/A	SFX
	Email received from wife	BDN	BDN	N/A	SFX
3	Email arrives	email arriving/application	short soft bell	high	SFX
	Email arrives	email arriving/application	short soft bell	slightly different pitch	SFX
4	Turning on computer	Finger on switch/fan of motherboard	clicking/whirring	mechanical	SFX
	Launching email	hard drive	whirring	mechanical	SFX
	Launching email	computer speakers	rising triumphant	musical	Music
	Email read	computer speakers	short sparkle	musical	Music
	Email received	computer speakers	2 positive chords on a vibraphone	musical	music
5	Turning on computer	computer engine	computer fan, beep, Microsoft start-up	computer	SFX
	Hearing mail alert	putting book down on desk	knocking	object knocking on desk	SFX
	Hearing mail alert	email arrives	computer sound	beep	SFX
6	Turning on computer	computer starting up	Hum or ding when done	digital	SFX
	Launches email app	application opening	swoosh	digital	SFX
	Indicator of Email being opened	application signal, email open	ding or trilling	digital	SFX
	Email received from wife	distinct for the person	speech of person	organic	speech
7	Launches Email app.	click of mouse to launch email from desktop	"click, click"	Computer	SFX
	Email received from wife	audio triggered by email, email programme	i would imagine you could personalise it	whatever you want	All.

Table A.2: Scenario 2. Participant sound choices and categorisations for the ADs.

Figure A.3: Participant 3, scenario 1.

CUE SHEET/SOUND MAP/SPOTTING SHEET. List of things that trigger sound

Page Number 1 Scenario Number 1 Participant number 1

TIME and PLACE Street, morning CHARACTERS John

Actions	Objects	Attributes and descriptions. <i>What do you know about the action or object? For example, Does the action or object have a size, quantity or a type? Is there a location in which the action or object happen/exist in? Does the action trigger another action or event?</i>	Do you associate sound with this? (Y/N)	Cause of sound	What the sound may be	Length of sound	Type of sound	Music (M) Speech (S) Sound Effects (SFX)
	iPod	music machine with earphones	N					
Walking outdoors		urban space, traffic exercise	Y	traffic	Cars, engines hum	1	rumble	sound effect
	in-car headphones	music, in ears, discomfort	Y	iPod	music	1	musical	music
listening	H		Y	music, traffic	music, cars	1		music SFX
changing track	iPod	hand in pocket on iPod	Y	iPod	abrupt shift in music	1	musical	music

Figure A.4: Scenario 1

## Appendix B

# System Usability Scale

(Brooke, 1996) SUS Usability Scale. Used in studies 2, 3 and 4.

To calculate the SUS score, first sum the score contributions from each item. Each item's score contribution will range from 0 to 4. For items 1,3,5,7,and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SUS.

### SUS Questions

When a SUS is used, participants are asked to score the following 10 items with one of five responses that range from Strongly Agree to Strongly disagree:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.



## Appendix C

# Surveys and Transcriptions

## Study Two

### C.1 Transcriptions and Thematic Analysis Phases 1-4

Added below are the transcriptions from all 9 participants. These demonstrate phases 1-4 of Braun and Clarke's six phase stages to thematic analysis Braun and Clarke (2006).

Time Code	Comment	Person	Action	Topic phase 2 (main)	Topic phase 2 (sub)	Description /code phase 3	(Thematic map 1) phase 4
00:55.7	so, i just play around with it do i?	p				Happy to explore from the outset. More confident	exploration
01:08.0		p	selects options in column 1-5 and u menus				
01:32.6		p	Moves to main cue sheet to select options for event one				
03:34.1	I got a question, so your using monitoring to monitor electricity, so assuming that the electricity is steady and consistent for some time but you still want to know if the change does occur ?	p		1,3	1	confusion over task and/or over scenario	
04:43.6	Just wanna check them	p			5	Goes back to check choices	Tool support
04:43.6		p	goes back to look at options in event one	5	1	see above	Tool support
05:40.4		p	Moves Cue sheet interface to look at time-line	3,5	1,2	explores time-line early on. Explore relationship	Tool support and exploration
05:45.7	So what's happened is this is here as result of you marking out your event, this is the sound design suggestion, its just so you can see what's happened	p					
05:59.1		p	flips back to look at Cue Sheet interface	5	1,2	looks between interfaces	
06:06.3	so its come up with a whole load of sound design suggestions as a result of your event in the time-line. So, this is your first sound	p		2,4,5		understands after i talk	Learning/ audio feedback during design
06:08.9	ah cool, can i play it, see what it sounds like?	p				demo	
06:29.7		p	Open up examples for her to look at				
06:38.4		p	play example to match first sound design suggestion				
06:44.3	so do you want to move onto event two?	p		5		Now moves to event 2	exploration, hear audio
06:46.1	uh yeah, can i change it, is that what its for? oh no 'cos you said we're not going to, we're not assessing the sounds now	p				wants to play even no knows they can't	
06:57.8	its good to know, you get though that thats is what would happen?	p				Moves to event 2	
07:04.2	yeah, alright. Event two	p					
07:17.4		p	starts to select options for event 2. Starting in col 6			not starting with 1st req.	
07:44.2		p	Reaches theme column (11) of E2.				
07:44.2	ok can i change my other ones	p		5	1	wants to go back to event one. After looking	tool support
07:46.1		p	moves to theme col (11) of E1	5	1	goes back to E1	tool support
07:50.6		p	re-does col 10 of event 1	5	1	iteration	tool support
07:57.9		p	re-does col 12 u-menu 1 of event 1	5	1	iteration	
08:02.0		p	does col 12 u-menu 1 of event 2	5	1	iteration	
08:08.2		p	selects u-menu 2 of col 12 E2	5	1	iteration	
08:15.8		p	does col 10, col 11 E2	5	1	iteration	
08:21.2		p	checks col 9, col 10, col 11 e1	5	1	iteration	tool support
08:25.7		p	checks col 12 u menu 1	5	1	iteration	
09:01.7	so we've got that the information stays the same	p		1,3	1	Requirements	terminology/und erstanding
09:24.3	OK so what if it changes if it increases?	p		1,3	1	see above	terminology/und erstanding
09:43.6	Might go with repeats. If it stays the same,so its not changing,then we will go with that. Can I just check them again...	p	(laughs)	1,3,5	1	Understand transitions, iteration and integration	tool support
10:12.0		p	checks through them	5	1	goes back to check choices	tool support
10:22.0	Cool, finished	p					
10:27.0	What's happened is you have now (show here the timeline),its given you some, this is just for you, i am gonna work on this but its so you can see what different parts of the sound were being affected according to what information you wanted to sonify. So you have gone from being neutral and steady to a slight rise in (plays two sound samples for 2 events)	p	(play samples)			explain	
10:53.8	That's really good	p					
11:21.5	Cool, that's really good	p		4		after hearing audio seemed to like method and concept	Hearing Audio
16:14.7	What other scenarios do you have?	p	post survey	4			Hearing Audio

Figure C.1: Thematic analysis. Participant 1.

Time Code	Comment	Person	Action	Topic phase 2 (main)	Topic phase 2 (sub)	Topic phase 2 (sub)	Description /code phase 3	Thematicmap phase 4
00:22.1	Its complicated?	P	Looks at Cue Sheet(cs) interface.	1,3	1		complication look of interface to start	Interface
00:56.1	you have got 2 interfaces. The sound map and then underneath you have the time-line which will play you back the sounds we design, but we will get there	R	move Time-line/CS to reveal timeline					
01:09.7	I'm a bit confused sorry, should i play a sound?	P		1,3	2		confusion look of interface	Interface
01:20.6	no ok, so you read through a scenario	R						
05:28.4		P	col 6 (misses out free text box) selects "location, environment"					
05:31.9		P	col 7 organic					
05:43.7		P	col 6 text box					
06:23.4		P	col 8 option 1, col 9 option 3					
07:28.2		P	col 10 - constant (option 2), col 11 themes= positiv. Changes to neutral	5	1		iteration	tool support
07:42.6		P	col 11- repeats, col 11 - option 2 (chose 1 list but changed it)	5	1			tool support
08:31.2		P	E2: col 6 text: ?, col 6 option 1 (environment or location) checks it twice	5	1			tool support
09:16.9		P	col 7 industrial (misses out menu 2 in this column)					
09:19.4		P	col 8 option 2, col 9 option 1, col 10 discribe (option 1), col 11 option 3 (negative), col 12 (changes due to increase). col 12 option 2, changes to 1	5	1		changing choices.	tool support
10:20.5	i am going to show you now. So that was your sound design, based on the information you want to set to sound.	R	Referring to CS					
10:20.5	So its given you some sound design suggestions based on what you've put	R	Show her TL					
10:39.1	OK	P						
10:41.5	What you can do, this is just my next stage development	R	show sounds -out of presentation mode					
10:50.7	So your first sound you said, steady and constant and neutral. So thats your first one	R	play E1 sound - (number 1)					
11:02.5	and the other one it was rising and it was negative	R	play sound 2 (actually option 8)					
11:07.5	Yeah, that's event 2	P		3	2		seemed to understand events when heard audio	
11:09.1	so your alarm would sound something like	R	play them both one after the other					
11:15.8	this is one, err, across the thresholds, just increase?	P		3	1,3		relating mapping to the sound she hears	
11:20.8	yes, so the increase, its rising slightly	R	play E2. Then play both again one after another					
11:20.8	OK	P						
11:29.8	so basically you have designed that sound by filling out the information here. So in the future, you would be able to alter these and alter your sound	R	point to CS					
11:46.6	ahh OK. What about event 3?	P		3	2		comprehension after demonstration and time	Learning
11:48.7	there isn't one for now. But in theory a scenario can have as many events as you like. All the sounds would blend	R						
11:56.5	so this is live, event one is er, ok? why is there three style (samples, sounds)	P						
12:08.9	no, this is for me. I don't want you to see its not under. its for the different combinations you might have put	R						
12:19.5	so maybe the list 4 is for the first event?	P						
12:24.9	oh..i get it (laughs). I got confused	P	(laughs)	3	2		study set up /study confusion?	Interface /study design
12:41.9	is that all, is there another scenario?	P						
		P		3	2		comprehension after demonstration and time	Learning

Figure C.2: Thematic analysis. Participant 2.

Time Code	Comment	Person	Action	Topic phase 2 (main)	Topic phase 2 (sub)	Description /code phase 3	(Thematic map 1) phase 4
00:07.0	so yeah you have got 2 interfaces here. Cue sheet and Time-line, where your ideas get placed in your scenario	R	show cue sheet (CS) and then time-line (TL)				
00:52.6		P	col 2 option 1, col 3 option 3, col 4 energy, col 5 user turns system on (option 1), col 7 option 1, col 7 option 4, changes to 5			iteration, checking ideas	
02:51.1		P	col 8 option 11 (amount?), col 9 behaviour = option 3, col 10 option 2 (continuous)				
03:06.8		P	E1: goes back to col 6 text and changes it (opt.)	5	1	iteration, changing ideas	tool support
04:50.6		P	E2: col 6 text box: col 6: environment/location				
05:23.6		P	E2 col 6 re-checks and picks option 2 (object)	5	1	iteration, changing ideas	tool support
06:32.1		P	E1 col 7 option 1, col 7 op 1, col 8				
07:27.5		P	E1 col 7 option 1, col 7 menu 2) chooses option 1	5	1	iteration, changing ideas	tool support
07:41.1		P	Col 8 option 9				
08:07.1		P	E1 Col 9 option 1				
08:15.9		P	E1 col 10 -cont, E1 col 12 opt 1, col 12 (menu2) opt 1				
08:40.2		P	E2 col 8: option (last in list)				
09:28.4		P	E2 col 9: last in list (op 3?)				
09:34.9		P	E1 goes back to col 9 E1 (option 3)	5	1	switches between events	tool support
09:46.1		P	E2 col 10: op 1 (discrete), col 11 positive				
10:16.8		P	E2 col 12 (menu1) option 4, menu 2 (option 2)				
10:29.4	Can I ask, actually about the meaning. The user, talking about event user turns system on and electricity use is steady, I'm confused, actually I'm not sure. I know that this is similar to the 1st one I did- so the object, no I can't ask you that, must be myself, this idea.	P		3	1	confusion events and scenario	/study design event comprehension
10:58.1	no, if you have queries then ..	R					
11:01.1	yeah, i have I'm not sure - it should be the system, like, it could be an on-off. switch or the electricity that i am trying to capture ..but i shouldn't ask	P		3	1	asking for help to understand events and scenario. Event confusion. Perhaps 2 events as before?	study design
11:23.1	yeah you should because if its a design for?err, it would be good if it is the electricity you are trying to	R				confusion over what designing for (user/ electricity?)	
11:26.1	yeah because i see this as well i am not sure if this is for mistake or you try to hint, actually its a good hint..electricity	P				is this my error and misunderstanding of what she was sking (ie about the events)	
11:38.6	well, its all electricity..	R				iteration when learns its about electricity	tool support
11:41.8	yeah its all electricity, sure, thanks. So i need to change a few things again	P		5	1	switching and changing mind on previous selections	tool support
12:06.1		P	checks E1 col 7, E1 col 8 option 10, E1 col 9 option 3, E1 col 10 option 2, E1 col 11 themes - neutral, E1 col 12 option 2, changes to 4, menu2 option 2	5	1	changes previous choices	
13:37.1		P	looks at time-line	5	2	explores time-line	tool support
13:57.5	ok, i ready, so i can check	P	reads out loud- 'hard effect', sound of object				
14:07.2		P	'...'synthetic'				
14:20.8	i can't do anything? it just tells me	P		3 (ti)	2 T1	Observation (neutral)Prescribed sound design_options	creativity and support / audio choices
14:28.5	this is just suggestions, so say you were kind of thinking you would like to know a bit more about what is going on with the audio, thats an example. And then I will show you what ?er the reason that its not on this interface is because it is in development.Its not under test, this next bit, but i will show you so you can get an idea of what happens and do you do this to others?	R					
14:45.9	Yes	R	Reveal the sounds				
14:56.5	so you said steady, neutral to start with	R					
15:05.0	mm-hmm	P					
15:05.0		R	I ..play option 1				
15:05.0	and then rise	R	play option 8				
15:10.9	OK	P		3	3	2 understanding after hearing audio	audio design process

Figure C.3: Thematic analysis. Participant 3, part 1.



Time Code	Comment	Pers on	Action	Topic phase 2 (main)	Topic phase 2 (sub)	Description /code phase 3	Thematic map 1) phase 4
00:20.1	So i should just point out that basically i am testing the early stages of the method rather than the sound design..	R					
00:23.1	sure, OK	P					
00:23.1	its more about the sound design in place , where it is in the method steps, if you get me	R					
00:26.8	So you have got the cue sheet and then you have got a timeline here, where the sound design suggestions come up, but you'll get there	R	point to CS and then TL				
01:48.4		P	E1: col (time) tries to click on it	3	1	not understood task fully?	Study Design /interface
02:00.0	so i press start, shall i just wait? but where is the written event though? isn't there meant to be a written scenario?	P		3	1	understanding of task	Study Design /interface
02:00.5	no carry on	R					
02:09.1	Ok sorry, here	R	show him written scenario				
02:53.0		P	looks at col 6 menu				
04:21.8		P	E1: enters text into col 6 text box?				
04:31.3	so imagining I'm giving it an identity , yup,	P	E1 col 6				
05:38.7	that's interesting I'm not used to think?.erm.	P	Chooses object	3,1	1	signs of understanding	terminology,
05:57.7		P	E1 col 7: option 2, looks at col 7 ** changes col 2 menu 1 to option 1 , then back to option 2	5		Thinking about information in this way	Iteration / column dependency
06:07.2		P	E1 col 7 menu 2 - option 3			changes after looking at later options	
06:38.5	erm, when you say what do you want the audio to communicate is that a property of the foley or of the information you ref..because you say 'what is the information that needs to be represented' (col 6) so it's the same thing	P	E1 col 8 looks, and then col 6	3	1	lack of comprehension of requirements between col 6 and 8.	terminology
07:08.8	Yeah, I mean it's	R					
07:12.1	OK.	P	E1 col 8: option 11				
07:29.2		P	E1 col 9: opt 3 (2nd from last)				
07:44.5	so it moves up first and then it remains steady	P	checks again - so it moves up first and then it remains steady			understanding scenario and events	
08:19.4		P	E1 col 12 menu 1 option 2, menu 2				
09:19.1	so transition into event 2 you mean?	P					
09:24.9		P	E1 col 12 menu 1 changes to option 4	5	1	changes ideas	tool support
09:33.6		P	1 col 12 menu 2 = option 1				
09:55.2		P	E2: col 6 text box= ?				
10:36.9		P	E2 col 6 menu 2 = goes back to E1 Col 12 menu 2 (transition) selects option 2	5	1	iteration goes back, changes	tool support
10:41.6		P	Back to E2 col 6, selects opt 3 (character)				
10:50.3		P	E2 col 7 looks, then at menu 2 goes back to col 6: menu 2 and changes to object	5	1	changes, iteration	tool support
10:54.8		P	col 7 looks at menu 1, menu 2 option 4, menu 1 option 1				
11:26.9		P	col 8 option (5th from bottom) opt 10				
12:13.6		P	col 9 opt 1, col 10 = discrete, col 11 themes = negative				
12:56.4	so now I look at the timeline?	P					
13:15.5	Yeah, so the idea is that its now given your different events have been given some SD suggestions based on what you put in and the transition. But this is all kind of working progress, but these are like SD suggestions based on film sound and stuff	R				Im explaining	
13:41.1	and then this is just, you kinda got (plays sample 1 and 2) some suggestions based on ... (move mouse) . so there is a watery sound there because you put water in and then you said it was a negative thing	R	Highlight samples, play samples 1,2 and 8 (negative)				

Figure C.5: Thematic analysis. Participant 4, Part 1





	Time Code	Comment	Person	Action	Topic phase 2 (main)	Topic phase 2 (sub)	Topic phase 2 (sub)	Description /code phase 3	(Thematic map 1) phase 4
1									
2	05:59.2		P	Col 2: home, col 3: passive, col 4 energy, col 5: user turns system on					
3	06:57.5		P	E1 col 6 texts ?					
4	07:59.2		P	E1 col 6 menu = looks at then					
5	08:20.6		P	E2 col 6 texts ?					
6	08:31.6		P	E1 col 6 menu = looks at					
7	09:01.7		P	E1 looks at options for E1 col 7, col 8, col 9, selects 2nd to last option (behaviours)					
8	09:33.4		P	E1 col 10: looks, col 11 selects neutral				iterating, changing ideas	
9	10:02.0		P	E1 col 12: looks at menu 1 and got snack to E1 col 6 menu					
10	10:16.3		P	E1 col 6 menu environ/location					
11	10:40.4		P	E1 col 7, looks at 2 menus. for back to col 6 and changes to object. looks at col 7 options and changes col 6 menu to character. Looks at col 7 options	5	1		iteration. Possibly supported by cue sheet layout	tool support
12	11:13.7		P	E1 col 6 : changes menu to environ/location. Looks at col 7 menu 1	5	1		iteration	
13	11:25.7		P	E1 col 8: selects option 3.,					
14	11:31.4		P	E1 col 7 menu 2 selects option 1					
15	11:35.0		P	E1 col 9 option 2, col 10: continuous					
16	11:51.7	Are these events dependent upon each other so event 1 is? and event 2 follows event 1 so I have to (move ?) that you go from event 1 to event 2	P	E1 col 12 menu 1:	3,5	1,2		Confusion of event relationship and dependency. But seems to understand it a bit	filtering, logic
17	12:19.1	OK, yeah so it will be one sound and (think about) how they might transition	R						
18	12:23.0	OK	P	Col 12. menu 1= option 4, menu 2 option 2, E1 col 12 menu 2 option 2					
19	12:34.5		P	E2: col 6 menu 2 - character (looks at col 7 menus) and changes to environment/location	5	1		iteration	
20	12:51.6		P	E2 col 8 option 3, col 9 option 1, col 10-diescrete, col 11 negative, col 12- last option, col 12 menu 2-					
21	14:08.0	so the text can only be one word Have i got that right?	P						
22	14:21.0	OK, so you have got another screen	R	show TL					
23	14:25.2	so this is your time-line here . So you've got your events and its given you some suggestions based on your erm..	R						
24	14:25.0	ahhh OK	P		3,5	1,2		comprehension after seeing TL and not just CS	interfaces, tool support
25	14:33.3	hh, based on what I written	P		5	1,2	1,2,3	Understanding concept, flow after seeing TL and CS and explanation	tool support
26	14:35.3	yeah, OK so its given you kind of suggestions for what you can do with the sound and for event 1, event 2 and this is just a prototype for now, and in theory what you would be able to do is um (show samples) ..is um	R						
27	14:59.3	so each one of these would be a sound (point to events on TL) in your scenario so you could have event 1, event 2. So for example you said you were erm, you said environment i think and then you said it was steady and neutral	R						
28	15:17.8	yes, event 1	P						
29	15:21.5	which is.. just an example but, So this is just what the parameters have affected	R	play sample 1					
30	15:21.5	ahhh	P		3	1,2		understanding after demonstrated cue sheet and time-line and hears audio	communicating / audio in process
31	15:21.5	and then your event 2 was and rising slightly ..its subtle but. so the idea is that this, umm, your mapping out your scenario here	R	play sample 8					
32	15:21.5	and then you have got your kind of, interactive timeline. And, you know, Youd be able to go backwards and forwards and think about the sounds as well anyhow they are affected. But this bit it is just this bit mainly that I am looking at	R	show time line, then CS					
33	16:06.7	Ok, so based on the sounds can I change mine?	P		5	1,2		Understands concept that what put in CS affects SD in TL	tool supporting integration
34	16:10.2	yeah, but to be honest, for this study... yeah, you know, in the future you can do that and it would directly affect the sound but for this study i just had to map, just to demonstrate how it works . Because I can't do the whole things its just too massive ? but in theory, yeah, you will be able to change these and then you will have different sounds and compose? does that make sense?	R						
35	16:32.9	yeah, yeah, yeah .. because for example I would now hearing these .. the industrial sound-maybe i would go rather for the other one like the organic (shows me col 7 menu 1) whatever that is , because the sound is like a server, you know like a fan,	P		5	1		Changing sound based on req. put in CS	cue sheet supports iteration
36	16:59.9	but you can see in theory that what you are doing is designing your own sounds for the interface and you can kind of iterate between them , the results and the	R						
37	17:10.6	yeah yeah the other? nice	P						

Figure C.7: Thematic analysis. Participant 5, part 1.



38	18:39.0	i wasn't sure about this one because , i mean, i mean they are basically not that difficult to use but the problem is the inter-dependency you know when you change something and you? yeah, it took me a bit to understand that , this effect	P	looking at transitions on cue sheet	5	1	t1	The dependency of one parameter on another and the filtering	dependency
39	18:59.0	yeah, i saw that you went through them, that's OK	R						
40	23:03.1	so , er, this is based on the one sound i heard? yeah because in my head i had something like modem ('beep,beep, beep'). Something more like this so sound, so i don't know .. i don't know..i mean i have to go with the sound (i heard?)	P		4,3	3	t1	Limitations of heard sound. Implementation vs concept. Terminology for sound	dependency
41	23:22.2	yes, don't worry	R						
42	23:25.7	because then im not that familiar with the categories because i don't do sound , so i don't know what i have ..what industrial is , you know thats the main problem i think ..i mean i personally couldn't match . i don't know what industrial means in that context	P		1,3	1		terminology, not seeing herself as someone who 'does' sound	terminology /target users
43	23:49.4	it might not mean anything, thats the thing . Maybe its because i can picture.. you know, i can hear. and then i may be assuming	P						
44	23:52.5	exactly, and then other people will (?) don't know, yeah its difficult, i don't know because i think because i design just by listening because i am not a pro , by listening to a lot of stuff and then choosing one that i like (?) i don't really care about the categories you know	P		1,3	1,3	t1	doesn't want to design using these categories. Text for design is problematic. Target users doesn't care about mappings. Design by listening	audio in process
45	24:35.5	but how would you find them in the first place?	R						
46	24:40.5	apple loops	P		1,2,3	1,3		familiarity, confidence with sound design. Would use apple loops. Design by playing with preset loops	audio in process
47	25:08.8	and then you have a general idea of what it could be, i mean yeah, its probably a bit different if you have experience	P					experience vs novice (FQ1)	
48	25:08.8	no this is really useful	R					usefulness	
49	25:16.7	yeah, this is what i am trying to bridge somehow is that kind of, you know, taking something that is really quite hard for people, i mean like thinking about interface sound and AD's and what are they? and making it somehow more easier for designers. Its really hard, its like that knowledge that i sort of know and i can't just study everything ,and well its like, how do i even begin to do this , yeah this is challenge	R					acknowledge challenge of making means to design Ads easier	
50	25:40.7	its really tough.. yeah because this is why you have people who do sound design, you know, because you need the experience .. the knowledge in a way and yeah?sorry i	P					experience vs novice (FQ1)	
51	26:02.7	no i think there is a solution, there is definitely a solution to that .. um i'm pretty sure there is	P						
52	26:21.6	yeah, its freedom versus quite a restricted , um, a guidance tool which, you know, it might have the filtering and the automated things which actually might be a good thing if its accurate but at the same time it might restrict what your picturing or what your wanting to have but at the same time (??) it might just open up the .. it might make you start to think about the sound and the fact that its designed and its all placed and its not 'just there'	R						
53	27:06.9	yeah so what i would do is go back and see what else it gives me, and then change the parameters	P		5	1		Changing sound based on req. put in CS	tool support
54	27:09.7	so thats great. So you would go back and forth and listen and test	R						
55	27:13.4	yeah and maybe there's a way to make??	P						
56	27:20.7	yes you could do , i mean if you go now and you fiddle with some of these you will see the text change on the sound design suggestions	R	i demonstrate					
57	27:50.7	it won't change it there .. that was just for the study. Just for the study i had to map.. its not really accurate but its for you to see how the method steps ..(??) next step will be?	R						
58	27:50.7	its a prototype (yeah, mm	P	tries to play the sample 1					
59	28:16.0	so its more about the method steps	P						
60	28:25.8	maybe a range would be nice, like not just one sound but several to choose from but maybe also like so i can.., cos, there is this transition between both categories i guess, like there's this area where they can overlap between them and so maybe you notice that your going down to the organic (laughs) yeah its true but i think if you find those sounds more interesting and so then it makes you switch categories, i don't know if thats possible .. yeah, i don't know i'm just brainstorming	P		5	3		Further ideas for sound	options
61	29:22.0	no, this is great its really useful. Because This is who it is targeted for, its meant for people like you , who have got interaction experience and know about it but not sure how sound? er so its perfect. Honestly your feedback is really helpful, thank you	R						
62	34:22.7	yeah yeah your welcome, its really fun i am looking forward to seeing another version	P		4			Fun. Looking forward to further versions. Likes idea but needs development	
63	34:31.8	if you want to come and have a play when get some more sound to play with , because the next step is that you work with the time line , yeah, you knew, the sounds and you can start to move them around and so yeah this was just to get an initial feedback on this bit	R						
64	34:58.2	if something else comes to mind then i am going to send an email	P						

Figure C.8: Thematic Analysis. Participant 5, part 2.







20:42.0	OK, so I have got the option to review , so I can review it. OK, so, event I i called this 'hard effects' what is that?	P		1,3	1,2	terminology, musical terminology	terminology
20:50.0	These are just sound design suggestions and you will be able to play these some sounds based on these suggestions and it is just o give you guidance really but they are not clearly um the first bit was, that the first bit of the method. um I will try and explainum! these ..i want you to look at um, the layout of them I think .. anyway i would just like you to look at them and tell me.	R					
21:17.0	OK , yeah 'um so who is the target for this?	P		1		FQI target audience	
21:24.1	'Is , ' i want to work with positive ' , its before? also WCI designers who haven't got much audio experience you might kind of think...	R					
21:33.6	OK	P					
21:35.6	an interface designer who has not really got....	R					
21:40.1	yeah, I think er. I probably fall under that you know. I know a bit about sound but I am not familiar with synthesising sounds and stuff, i don't have that kind of knowledge, so er...	P	1	3		FQI target audience	terminology
21:51.0	you are the, I am getting people who are the type of audience to do the study ?	R					
22:05.8	So i guess my 1st impression if i'm being naively honest is... so, my ... i couldn't basically relate these things[...].With the decisions i had made in the previous ones.	P		5,1,2		relating CS to TL	
22:09.8	Like for example, i had all this kind of time, context, listening, theme, Foley and then i came here (...). I found a whole different set of things, type of sounds. I don't think it's that familiar with synthesising sounds and stuff, i don't have that kind of knowledge, so er...	P		5,1,2,3	1,2	relating CS to TL interface issue. interface issue. interface issue. ideas (method update)	
23:09.4	or event the other things, the foley , want to know and these things over here, but anyway, these just my expectations and um, interfaces you know sometimes you just have to get used to them .. so , OK, um	P		5,1,2,3	1,2	comments on it being an interface issue	
23:09.4	yes, the context, the listening....	R					
23:25.2	For Event 1 (Looking at TL) you are saying that , so the system has given me some suggestions of what i , ..the sound should sound like .. hard effect, sound of the object , musical treatment , instrumentation, synthetic instrumentation, parameters, and i don't know what hard effect means	P		3	2,1,2	Full understanding of time-line. And gets the link. Terminology	
23:35.3	yeah its like the sound of something, so if i wanted a car engine . Its like the actual car engine and i would like to hear it and record the buzz of electric or .. the actual noise of the thing rather than	R					
24:14.6	ah, OK, where is that coming from "hard effect", what's the term	P		1,3	3	Terminology and why I chose this	Lack of explanation of foundations and
24:17.0	its from a , all this stuff come from literature actually i have just been through various bits from sound design and , but i need to, um this is all in the database that i need to develop	R					
24:27.4	OK, so sound of the object meaning what , you are doing the whole sort of	P					
24:32.4	auditory icon	R					
24:34.4	well, yeah and i was going to say the active, what is it called, the ecological (yeah exactly), framework i think	P		3			
24:44.9	as opposed to earcon which is abstract, so if you had said i wanted to sonify this and there wasn't a sound to relate to it , i would have given you more of an abstract suggestion	R					
24:54.4	yeah, so my sound would be , you know, this is a car rather than this is a low burring tone of something like that, ok fine. And so for the transition...(.), going from the sound of a car to the sound of a low burring tone, the volume , the volume might be contested by some designers, but ' start the next... (laughs)	P		1		sonification suggestion based on the sound of the car and use of his research in sonification	
25:17.0	I mean, what?	R					
25:19.2	um, well because you have that cross effect don't you with the two and the pitch and some people might perceive an increase in amplitude as a change in pitch	P				issues of sonification	
25:31.0	"start next event with a similar audio qualities". Now similar to the previous one or what? so you are suggesting that the sound of the car is similar to the sound of the car, what is the sound design? and then, or, ' make make a rise and then go to this melody (...)' "follow rise and follow action"	P				looks at E2 suggestion	

Figure C.12: Thematic analysis. Participant 6, part 4.





134	30:29.8	Yeah, you can hear that. Its interesting because there is a chord underneath one is major and one is minor but its subtly done , er might no (...) [ok and then the] plays ? , thats not got any (?)	R	play 8 and play 9 again. Play 7					
135	30:29.8	OK	P						
	30:54.8	I mean what its doing is its taking some kind of musical thing , awkwarding it for you, you know its saying..so for example the neutral one you have got no.. you've gotta missing out a 3rd , basically in music its , if you miss out the 3rd its not positive or negative its neutral because you have not given it a key.The 3rd isn't either major or the minor and that will , it makes it major or minor, so its just awkwarded like that. I mean its not really a key, its just a bit of a trick that we were doing it so you can kind of go 'oh ok' , and then you might kind of go what happens if i change this now (point to CS) and then you can fiddle around with this (TL) and then slowly start to get used to how they inform each other a bit	R	point to CS then TL					
136	31:42.9	so.. what about other things.. what about this sort of melody versus (...) no, where were they. Regular rhythm versus spatilization .. do yo have those?	P	looks at TL	3	3			curious about mappings
137	31:58.8	no, I mean, thats the thing have got lots of bits and pieces in there but for the sake of this study I had to (?) limit [...] thats the idea that you can kind of begin to see the links and get some ideas and feel a bit more confident using audio	R						
138	32:32.0	So I am just thinking, like, if i'm very curious then.. about, all of these design things and harmony and stuff like that then this would be nice to have (showing TL) and then I can come back and see what you've got. But if i am not really interested in that, then do i need to look at this? What's the advantage of having this?, its a nice overview, but if we are just being practical and i just want to produce something i would probably just want to see this right? (shows CS) and then somehow have his background, have this sonification playing and then i can hear it and then i can see what you've got. But if i am not really interested in that, then do i need to look at this (highlights TL) or maybe just go to this (moves to R2) and see what the transition sounds like and then.. because you know i don't care about harmony and .. i just want to get the sonification done? But if im curious about things then i can come here (TL) and i can get a nice overview of how my choices are mapped to actual sound design knowledge , umm	P	showing TL, shows CS/highlights R1.moves to R1, back to TL	1.1.2	T1		Differences between catering for people who are interested in design processes made explicit and those that do not.	Level of explanation/ tool options to see logic
139	33:41.3	or you could do all of this and hand that to a sound designer and help and they go..oh, OK , cos you have got your scenario mapped out	R						
140	33:50.9	Yeah, OK, cool. So whats the question here, I mean, I	P						
141	33:55.4	the research question ?	R						
142	33:58.0	Yeah, whats the, whats the?	P						
143	33:58.0	Well, its started off with looking at sound , er, composition, film composition and that was a bit kind of, er fill look? then it was , i realised that what i was looking at about (?) was i really wanted to find a way to help people create auditory displays that was accessible and kind of, um, thought about aesthetics a bit more as well .. um i dunno, i kind of like the idea of mating something that seems quite abstract to people a bit more useable ? um so yeah, i guess looking at soundtrack composition in that its looking at a sort of event-based narrative of what happens to the sound	R						
144	33:58.0	OK	P						
145	33:58.0	You know like game audio you have events that are non-linear but they still work in any order [right, yeah], so you have got principles of that?and that then , the idea is that you have got these libraries and stuff, you have already got quite high-end mappings already you have got quite high-end suggestions , you can go to a sound library to get a sound, or a sound effect [yeah], so its kind of ideas around that ..er	R						
146	35:16.0	so, are you comparing this to something else? thats kind of the phd thing, right.. you know, are you trying to, so , are you doing this thing to get some feedback on the design then, then how do you know that this actually helps make the design process	P		6				challenges of evaluating design approaches
147	35:39.0	by asking for feedback, and well yeah, auditory display works, yeah, i dunno. Well, i mean	R						
148	35:47.8	its like, because evaluating these kind of things, evaluating design approaches is just a really hard thing to do. Like how do you know that this actually helped? convincingly, you know to an examiner say, or something like that? like whats? so, do	P		6				general challenges of evaluating methods
149	36:20.0	Yeah, i guess i have to because it is only going to work if the display works ..um, there are loads of toolkits and methods though aren't there?	R						
150	36:30.4	I was going to say i mean what else is out there in this kind of, this kind of fashion?	P						
151	36:34.7	there is a few, ... in sweden a study where they did an interface and you and a picture and you looked at the scene and there is the interactive sonification with Hugi, in alborg who has done , they look at things like use-case scenarios and how to sonify	R						
152	37:06.1	right right	P						
153									

Figure C.14: Thematic analysis. Participant 6, Part 6.

[illegible]

Figure C.15: Thematic analysis. Participant 6, part 7.



168	46:16.8	What if i say repeats , what happens? [...] 'repeat motif' -yeah OK	P	Looks at TL	5	3	1,2		
169	46:25.0	OK, its just some	R						
170	46:25.4	so maybe like a bug or something . Lets try again [...] No its not changing... but its supposed to change to something right?	P	(goes to CS and selects stop) (then looks at TL).					
171	46:39.3	it should be yeah but	R						
172	46:41.8	This is the screen right? (TL). I think it is is not very clearly laid out , uh i need the labels.. more than anything else and then transitions, uh yeah, just labels and then i would be	P	Looking at TL	3	2		improved labels and interface	
173	48:24.2	So i'm not sure about this i don't think its complex i just had some different ideas about like what i was expecting. So besides the labels on this one (TL) i the main thing is this idea of transitions that i wasn't sure.. ' that i don't really... Im still a bit confused. So id on't know if this should go to unnecessarily complex?	P	Doing SUS	1,3			Issue over transitions. Not necessarily complex more issue of expectation	
174	49:08.6	need the support of technical person in order to use this system? Well, having you here explaining it was necessary, but thats fine .. consistency i would like to see more consistent sort ofr, so with this one (CS) just so i know how i choices affect [what its mapping too)	P		1,3,5	3	1,2	having me explaining helped. Need link between mappings and req. made clearer	
175	50:15.5	any other things scenarios design audio for ? like other scenario sooother than this electricity thing? the only thing i thought about that would be cool is like, with these suggestions, because i'm learning stuff, im taking it as an opportunity right, to find more choices er maybe even things like those mini-pop-ups that do rationale for why this is..why this works...why a rise in pitch is good for this kind of transition or functional like that, that would be nice. But that would be for like a full, fully functional	P		6	3	1,2	future. Rationales for design and mapping choices that are suggested. Pop-up windows. Fully functional. Appreciate this is a early version, but	Interface vs. method
176	50:59.8	yeah, i mean there is big text box i could put a lot more in there?	R						design patterns
177	51:04.2	Well, you have that point you know when you pass your mouse over them at least there is this pop up or something like that . And the other major thing that i was thinking, is that we can have some design patterns on the page. Design patterns are all about design knowledge then you could basically i could see this linking to a design pattern space . So design patterns you could go to webpage and you could have all this different categories of things and then you, you know like this is design patterns for front page or this is design patterns for the operation or this is ..some form of categorizing design knowledge .. um, and i could see if that would be really boring to come up with this sort of page. But, you know if i could go to 'parameter-regular rhythm' i click on this and somehow i can see design patterns relating to this particular choice and i can explore the design patterns see other peoples , what other people has used it for ..it would be kind of like a nice r. its like you go to google and search fmo of course, but its .... Because there is all this work on auditory design patterns	P	3	6	3	1,2	Further ideas for linking to a design pattern space. Links to further info.	
178	52:11.2	Yeah, Chris Fraumenberger he did?	R						
179	52:11.2	so he created this sort of visualization.. so you could , you could, so well the idea is that hell now would this feed into someone actually trying to design something, Well, one way that this could feed into this s through a tool like this i suppose	P		6,1,2			positive suggestion of tool as front-end. Feed into something actually trygint to	front end
180	52:29.4	as a sort of front end ..	R						
181	52:31.9	so the front end would be like this, But if i'm curious to know more?(...)so the first level of knowing more is when i hover my mouse over harmony it tells me about what's the attitudinal feeling choosing harmony. Based on i can't even remember which box is the attitude word and then the next level would be clicking on the box and it would get a list of design patterns and then click on that find the examples. Yeah its cool	P		6	3	2	Idea for interface dev. Mouse hovering	Interface vs. method

Figure C.16: Thematic analysis. Participant 6, part 8.

	Time Code	Comment	Person	Action	Topic phase 2 (main)	Topic phase 2 (sub)	Topic phase 2 (sub)	Description /code phase 3	(Thematic map 1) phase 4
1	03:59.1		P	context (home), listening (opt 1), themes (energy), trans/triggers (opt 1)					
2	05:02.0		P	col 6 ..menu 2 first (character)					
3	05:47.0	so the information would be, electricity?	P	col 6 menu 1	3	1		Understand the info is electricity	Terminology
4	06:06.0	yes, you know its kind of how you interpret it really, but	R						
5	06:10.5		P	types electricity in text box					
6	06:24.4	so, when they turn it on, so i was sort of imagining , when you turn it on it would say, so they're turning the electricity on	P		3	1		expecting feedback from this action	
7	06:40.8	turning the monitoring system on	R						
8	06:42.5	the monitoring system on , right, because i was going to say that would be a bit weird if you were listening to .??, right, OK and so it give information about, erm, the electricity usage?	P		3	1		comprehension of info needs sonifying	
9	06:57.6	yup, so you've got your home electricity monitor ?	R						
10	07:04.4	umm hmm, but this is over like a specific time period?	P		3	1.3		time-issue and how to map this out using soundtrac	communicating/s tudy design/useful ness
11	07:07.0	er, so this is what it generally does, the system, and this is one example of a scenario , a use case	R						
12	07:12.1	i mean so when you turn it on are you going to get your electricity uses for all time or just for a day , just for the hour?	P		3	1		see above and understanding scenario?	Terminology
13	07:20.2	umm , thats a good question . I mean its, i haven't given it a time-scale as such for this one , um but it could be	R						
14	07:29.4	so it doesn't really matter	P						
15	07:31.0	no, i mean for this, no.. just for? but it could be that you have got a use case and it says that its on for 5 hours and the user goes and turns it off and you might think, well, actually i am gone to have a different sound because that is annoying and , you know what i mean, you could, .. the time would affect that. but your right maybe i should have put time in.	R						
16	07:49.7	or, er . Is it just like you've got this amount of devices on and they're using this amount of power right now	P						
17	07:56.7	yeah, yeah i mean it could be like that, i just didn't put time thing on it . I just thought about one events, two events	R						
18	08:05.8	recent useage i suppose..current	P						
19	08:07.5	no its current, yeah	R						
20	08:08.3	i think it was just the steady sort of word , confused me a bit hum.. because then if it goes over a desired threshold then there is a sort of spike in electricity .. so your using the kettle and the toaster at the same time or something (laughs) OK?	P	laughs	3	1		understand sscenario. But terminology steady confused her. Different events?	Terminology
21	08:34.7		P	col 7 Foley -option 1, menu 2					
22	08:46.8	what do you mean by inner-world, outer-world?	P		3	1		requirements for characters	Terminology
23	08:58.7	its sound..um	R						
24	09:06.2	would it be sort of er,inner world is like a personal thing or externally to yourself ..ok,	P	selected 'outer wrold'					
25	09:29.3	i can only put one word?	P	back to text box in col 6					
26	09:30.6	no, i mean i did that to make it easier but ..	R						
27	09:36.2		P	writes electricity					
28	09:43.8	eermm	P	col 8					
29	09:52.4	thats interesting because normally er, no its fine i won't tell you	P						
30	09:59.3	i'm gonna put weight because its going to be a measurement , but because thats the only measurement	P		3	1.3		Req mapping. Weight is the only one that maps to a quantifiable measurement. Limited options	terminology, options
31	10:09.2	its the only one there, yeah i get you	R						
32	10:09.6	i guess age is one,,, but weight is..	P	selects weight				or age is?	
33	10:20.3	you said it was steady	P	col 9, selects steady & col 10 option 1					
34	10:46.1	i'm going to put positive for the behaviour actually because if its steady and your not going over the threshold then its positive and your not spending money	P	col 11	3	1		understands mapping req. Nice approach - thinking about users feeling positive about it. Puts herself as user iterating through ideas, using cue sheet	
35	11:02.0		P	col 12, opt 4. menu 2, option 2	5	1			
36	11:21.3		P	E2 col 6: text box: 2 words, menu 2: character,	5	1			
37	11:39.1		P	E2 col 7: menu 2 first option 2, think menu 1 already had 'outer by default	5	1			
38	11:45.4		P	E2 col 8: option 2, weight?	5	1			
39	11:49.3		P	col 9 the character (opt 1)	5	1			
40									

Figure C.17: Thematic analysis. Participant 7, part 1.

41	11:55.2		P	col 10: opt 1, col 11: opt 3,	5	1			
42	12:04.3	um thats made me want to change	P	E2 col 12, menu 1 , selects option 1 'Then it stops'. goes to E2 menu 2 select opt 2	5	1		change idea based an options	iteration
43	12:30.5	yeh, OK .. slightly, it was like slightly confusing because um, the user and then the electricity use? so i could have been describing the user or the system - I decided to choose the system	P		3,1	1		Understanding difference between user being her as designer and being someone she is designing for	terminology / study design
44	12:43.2	yeah, so I think what i was trying to do was look at (i will show you the rest in a minute) but trying to look at the user as the, you know like you and I interacting with it, and like turning it off and on manually and like the system will be automated in that.. so if it went over a threshold but that just happened because it did it itself - so, maybe i wasn't clear about that?!	R						
45	13:07.6	well, yeah if i was to describe the user ..i guess it would be different, i mean- did you want me to do that as well?	P		3,1	1		User versus information. Does user need to be designed for?	terminology / study design
46	13:25.3	describe the user?	R						
47	13:25.8	yeah, with this er information?	P						
48	13:30.8	yeah i mean i did actually have user category but took it out	R					why did I do this now?	
49	13:34.8	oh, OK	P						
50	13:39.4	its fine, I mean its where to limit it.. Let me show you the rest and it will be less abstract . So whats happened is you've.. so you understand you had your event and looked at what information needs sonifying (yeah). And then here (TL) it has given you some sound design suggestions based on what you have put	R	show the time-line					
51	13:58.5	oh	P	seems surprised	3	2			
52	13:59.2	and how to go from one event to another	R						
53	13:59.2	yeah yeah	P		1,3,5	1,2		understands after I explain	Learning, tool support, communicating
54	13:59.2	smoothly and then, Its just, this is.. the reason its like this is because its a, its not..its working progress so it is a prototype and this is.. The method steps rather than the final mappings if that makes sense? So you can see how it works in principle. So you've got your suggestions and you will have the option to play sue sounds underneath	R	open up samples, plat sample 7				explaining about it being working progress	
55	13:59.2	So its giving you some.. thats a rising sound. And then you've got the same thing that's positive	R	plays sample 9					
56	13:59.0	So there is a major chord underneath. Its very subtle negative	R	play sample 8					
57	13:59.0	So they are just examples and there will be loads in there and there is a huge database behind this of sound design suggestions and mappings but its just to kind of guide you. And You can see	R	indicate to Cue sheet					
58	13:59.0	the idea is that you can kinda sonify all the scenario and see how it is affecting the sound choices	R	go to timeline					
59	13:59.0	And you can kind of go through and it ill change the suggestions a long here. So that is saying acoustic instrument because its natural	R	go to CS and alter menus- foley, menu 1					
60	15:11.8	yep	P		1,3,5	1,2		understands after I explain	Learning, tool support, communicating
61	15:15.1	and then	R	show TL					
62	15:15.1	I see, yep	P		1,3,5	1,2		unertsnsads after demo	Learning, tool support, communicating
63	15:21.7	thats the idea that its a tool to aid design	R						
64	15:30.0	right, so i can have a play with this?	P		4,5	2		wants to play after seeing TL	audio in the design process
65	15:30.5	yeah, so the , you can have a play. The mappings aren't .. the? sound designs. The actual sounds are fixed for this study because it is just to demonstrate that you would do this and then that and then there will be sounds. Thats the next stage is to work with the ..sounds. This was just to the, um, steps. If that makes sense?	R					explaining about sound samples	
66	15:54.5	OK, is there anything you need me to do in here, So are there any sort of instructions for this bit	P	looks at blank text box E1, on TL	1,3	2		confusion over use of time-line	Interface
67	15:58.1	no ..these are suggestions based on what you have put in the first bit ,1st interface and its to give you some ideas and then i think you can then go back and change it and then you can see how the sound design suggestions come up, It is just to give you an idea	R					explaining about mappings and options	
68	16:33.7	so these sounds ?	P	reads TL content	3	3 ?	2	understanding after explanation	tool support, communicating
69	16:46.0	yeah i mean this will be another interface that will have a nice playback kind of thing - its just um	R						
70	16:52.3	no, its cool ..um what this 2nd box for parameters	P	points to empty text box E1 on TL	3	3	2		
71	16:58.5	oh, its a in case, because some of them have got several sound design suggestions ..what is it harmony and then it might be rhythm and pitch	R						
72	17:58.3	(1)yeah, OK	P	explores TL	3,5	2		exploration	exploration
73	18:01.8	(1,2) so I can listen to these?	P	looks at CS..then back to TL:				wants to listen to the sounds	
74	18:10.4	yeah, i am not really asking ,..i mean, by all means give me feedback because it all helps the next.. but I am not examining the sound as such right now - its about the fact that you can see that you have done that and it maps to the sound, then you can go backwards and forewords between he scenario and the ? thats the idea	R						

Figure C.18: Thematic analysis. Participant 7, part 2.

75	18:32.3	yeah, I think it would be helpful to have (1) a summary of the event next to the?on this page (looks at TL)	P	Looks at TL	3	3	2	Links between interfaces to demonstrate mappings. And summary of events	reveal logic
76	18:44.2	yes that would be useful. Your not the only one to have said that actually, a previous participant said that, he wanted to see the links between the 2 interfaces	R						
77	18:50.3	yeah, yup and then, you know because a lot of this (1)	P	(1) looks at Parameter box E1 TL	3	2	2	understanding mappings.	terminology
78	18:50.3	so the parameters the high pitch and the major mode its actually relating to the (-)	P	looks at CS	5	1,3	1,2	understanding mappings.	terminology
79	18:50.3	when you said it was positive and negative and then i guess, yeah you wanna be able to link it up..(1).. er 'instrumentation'? this is, I mean, (2)	P	(1) looks at TL, (2) looks at CS	5	1,3	1,2	see above	terminology
80	18:50.3	its starts off quite abstract in the beginning ?'classify the information' (1) and that's interesting (2) because a character? yeah because all of these (character, object, location) are quite abstract things	P	looks at col 6, looking at drop down menu 2	1,3		1	abstract classifying information as character, object, location to start	terminology
81	19:33.1	yeah	R						
82	19:33.1	which is good, i like abstract	P					But likes abstract	
83	19:36.5	oh thats good to hear because there is a reason for them .. I have been umming and arring . They are abstract but I want to, its about soundtrck composition so its got to be kind of um..	R						
84	19:47.5	mm	P						
85	19:48.1	ased on what you look out for when create soundtrack and try and make it so that they have got characters, emotions and locations and kind of a bit more aesthetically pleasing and so this is like a way to make the sounds	R						
86	19:59.9	characters as in um , like characters in a film or something so people	P		3	1		Makes link to film and characters.	communicating, terminology
87	20:23.9	no, its interesting	P						
88	20:25.2	mm, its hard to know I don't know.. this is the hardest .. number 6 is the hardest one	P		1,3		1	Classiying info is hardest	terminology
89	20:31.3	you have got one missing, I guess, yeah. Because I put character but i didn't mean a person i meant the character of something	P		3		1	she meant character of something = characterization?	terminology
90	20:41.3	yeah, yeah, OK							
91	20:42.4	I guess (?? thats more? ) parameter? no , no	P						
92	20:45.8	characterisation? no , um	R						
93	20:50.8	like a descriptive	P						
94	20:52.3	descriptive like the character of something .. yeah a nature , er properties	R						
95	20:57.8	properties, yup. A property, yeah I think you just needed to add another one	P	col6, menu 2	3		1	make req. clearer. Add another one	terminology
96	21:05.5	OK	R						
97	21:08.5	yeah, ok. um?.. (...) 'properties of the object' (...) yeah. But i think thats still alright as then you can say (...), like the property of an object, you know, if it was like , sort of the descriptive word . Say, if its a range , if its? if it is a positive or negative thing, um , if its more abstract, i guess so you could have more volatile things, mores steady things, er.. you could probably go on for ever actually	P	col 7, laughs, menu 1	1,3		1	suggestions for mappings that are less abstract	
98	22:00.1	yes i think this is a problem with it , where do you limit it, i have to set some..? but making them clearer to understand and a bit less like (eh) would be good.	R						
99	22:07.8	yeah	P						
100	22:09.8	basically, the idea is that its kind of following this like?.you have got your character or whatever and then what does it do, and what happens as a result , its a kind of a narrative of the scene, the scenario	R						
101	22:22.3	so a character , when you say a character you mean its like a person and then you've got inner and outer world	P		3		1		terminology /design issue
102	22:29.9	yeah,	R						
103	22:50.1	i guess character you can have protagonist or...	P						
104	22:56.7	i did actually have that	R						
105	22:58.1	heroine	P						
106	23:01.4	or hero, stock characters	R						
107	23:05.7	yeah ..if thats useful i suppose. 'What the audio wants to communicate' (col8) . . . so i suppose if i was thinking about electricity i would say its a property ..the, er, what you want the audio to communicate	P	looking at col 8					
108	23:41.7	ok..lets go back to this (TL) ..huh..'type of sound. ambience' ?ok?	P	looks at TL	5	3	2	links between mapping and req. Where did ambience come from?	Event Relationship/I ntegration
109	23:56.6	yeah, cos its a ?its quite difficult to make the link actually . I mean, ?there must be like reasons why it does, why it sort of makes the suggestions .. so it might be interesting to see the reasons	P		3,5	1,3	1,2	wants to see links and logic between req. and audio. Difficult to make the link	Event Relationship/I ntegration
110	24:17.9	see the reasons, yeah thats fair enough	R						
111	24:19.4	but then I guess ?.. yeah otherwise its all like ?. if you want to you could have like a button saying information button or something , don't know , but	P		3		1,3	interface for further understanding. show/hide logic- how does this affect the design process.Options to access info.	Interface/sup port/knowledg e needed
112	24:41.3	yeah, a previous participant said he wanted the option to see , go further into the rationale behind why its there.. or not you might not want anything to do with the audio, so, you might just want to interact , but this is a good.	R						
113	24:58.2	x	P						
114	25:25.8	no, there's parameters in there that need to be inputtable	R						

Figure C.19: Thematic analysis. Participant 7, part 3.

115	25:30.7	yeah , because if its going to be , you know, sort of .. i mean you could sort of update the system user every now and then but its got to be quite .. i suppose you don't necessarily want it to just be really annoying	P			2	1,2		perhaps referring to changing sounds so doesn't get annoying?	
116	25:50.0	mm, no exactly	R							
117	25:50.6	and then you want to have the difference between if its been steady or been changed. And if its been steady you want it to be quite ambient	P			2	1,2		thinking about annoyance of sound . Suggests a mapping	Audio choices
118	26:00.6	yeah, yeah thats.. because its passive	R							
119	26:03.6	so thats why , i guess the rationale behind the	P	looks at TL and ambience in El:itype	2,3	1,2	2		Rationale important to consider usability, aesthtics	Audio / mappings
120	26:08.7	eah exactly, there is rationale behind the mappings . Looking at sort of .. there is huge database behind there pulling out all sorts of stuff, mapping and filtering - in a messy way at the moment, but thats the idea, it is kinda doing some logic that I can ? its not just abstract I have sort of designed it based on stuff, because others it would be well 'why have you chosen that' and I will get caught out .. so there is that. But i guess what I am saying is it would be nice for the designer who using this system to see perhaps why that choice	R							
121	26:38.9	yeah, to choose the ambience and then, because you've got another thing, transitions here (TL), which is, I guess where it would be a little it more, um, I don't know louder and 'listen to me'	P		2,3,5	1,2,3			suggestion/ looking at audio and how it integrates within whole story. Seems to want to take this into account with her design. Event layout.could argue method has is got her thinking like this	Audio choices
122	26:50.9	yeah, and the idea is that you've got these sounds, but they're not?they kind of go together so you can have 2 interface sounds or something and they are designed to blend or they sound nice together and you've got a bit of aesthetic thinking going on and also you might go , well actually in the use case number 2 that interaction happens before that interaction so I want to swap those sounds around	R							
123	27:14.5	yeah, yeah um, ok. I mean this is just telling you ..sort of suggesting things a bit it doesn't let you do..like make anything	P			4	2	T1	Suggestions only. Doesn't let you do anythng?	Sound suggestions. Creativity/su pport/restric tions
124	27:26.8	well, it will do , i mean, yeah.. the next bit .. this timeline here will be,, you can ? well, if you think about it you can go back and change the suggestions and it will change them here and you can listen and go oh well that might sound ?) so you can go back and change that and you can kind of get? work with your scenario quite iteratively	R							
125	27:50.3	yeah, you would think you would have a ..you could see all of it	P			3	1,2,3	2	interface issues and need to see all the relationships	interface
126	27:57.5	all at once you mean?	R							
127	27:58.4	yeah, .. but its gonna get quite large .. but i guess what you could do is have ? you could fill in this stuff (TL boxes) and then press the button and it sort of minimises itself but its still there so if you want to go back you can just maximise it but you can still see the suggestions at the same time	P			3,5	1,2,3	1,2	interface and further recommendations to support method based on that	interface
128	28:17.3	yeah so you have got the key information coming through maybe on some other interface	R							
129	28:20.4	yeah, and then .. I suppose once you have done it and you can listen to it and then if you wanted to change something it would be ? it would be because you didn't understand the event properly do you think?	P			3,4,5	1,2,3	1,2	listen as part of the design process	Audio /iteration
130	28:42.7	there is a difference between user events and system events and so you should make that clear. I am not saying that you need to separate them but?because there is actually gonna be a user event and a system event at the same time ***!	P			3	1,2		event clarity	Terminology / study error /event comprehension
131	29:05.4	at the same time	R							
132	29:05.4	yeah because it turns on?it says "ding"	P			3	1,2			
133	29:10.6	so the user turns it on and there is a noise and then the system does something , it goes over a threshold -so thats a system event . So you have got a user event first and then a system event	R							
134	29:24.3	But I would also say that this is a system event, because it measures it. I mean, when you say that the user just turns it on , they're just turning it on	P			3	1,2		event clarity	Terminology/ event comprehension
135	29:34.7	a trigger	R							
136	29:35.7	yeah, but it doesn't actually change what the system does.. depending on	P			3	1,2		separating user and system events	
137	29:43.4	so your saying that there are events going on after the user turns it on	R							

Figure C.20: Thematic analysis. Participant 7, part 4.



138	29:46.9	because , well you know I was saying about how you have got like an ambient thing which just tells you its steady and then something which tells you its changed. When you turn it on you would just get the ambient one because it wouldn't have necessarily changed the moment you turn it on, if you know what I mean?	P		3,5	1,3		event clarity and suggestions. Referring to an event to tell of a state change	
139	30:08.7	so it would just be , it would be system event saying I'm steady	P		3,5	1,3			
140	30:17.9	...it depends what your looking at	R						
141	30:17.9	I know what you are saying	R						
142	34:14.0	other scenarios' ?	P	filling in questionnaires					
143	34:16.1	Its if you have got any thoughts really	R						
144	34:22.6	my mums got one in her fridge	P						
145	34:24.7	oh really, how does that work	R						
146	34:24.7	beeps if its been open too long	P						
147	34:32.7	my mum has that in her fridge as well	R						
148	34:34.3	ovens ..I am just thinking household things now [...]	P		6			further scenarios	
149	35:13.1	ahh...something, a computer that ..yup, because I have had this before where i have got quite a dodgy program that i am working with at the moment, not because its liked cracked or anything, but just because its rubbish , and it crashes and it would be really useful to know whether i need to turn it off or just need to wait	R						
150	35:13.6	state of a computer	P		6				
151	35:15.9	what's it thinking	R						
152	35:15.9	yeah but it would need to be like from a slave drive of course, because if its crashed its not going to work	P		6				
153	35:23.0	the technical thing , its not .. its the ideal situation , in the future when we are all using audio	R						
154	35:33.5	time	P	laughs	6				
155	35:36.9	time? sonify time that sounds deep	R						
156	35:48.4	yeah, well it gets negative the closer you get to death ..no I'm kidding. I mean it could just be around events in the diaries and things	P		6				
157	36:01.9	body clock	R						
158	36:06.0	baking, ah yes, body clock thats a good one. When the plants need to be watered	P		6			further scenarios	
159	36:48.3	I guess, I mean they have sort of got this already, but in hospitals when you have got peoples vital signs . Yeah, i mean it sort of does this already	P		6				
160	37:21.4	So are you going to go through a cupola of iterations of this? sort of feedback at every point	P	Post Study					
161	37:29.0	feedback yeah	R						
162	37:29.0	thats a good idea	P						
163	37:29.9	yes, so you do something and you can hear what happens in the sound	R						
164	37:33.0	yeah, thats how you're meant to do design	P						
165	37:36.4	as I think so, but i had to evaluate something at this point and get some feedback on the whole thing because?if I had evaluated any one bit before connecting it all it would be kind of 'what is this...'	R						
166	37:52.4	yeah, I mean it might have been useful to know at the beginning that you were mapping soundtrack things to these sort of systems ? and then I would have known that character was character	P	laughs	3			lack of expansion of concept. Study design	communicating /comprehension/study design
167	38:08.4	yeas, thats good because I didn't know how much information to give and how much ? its the usual design sort of?.. design of a design tool	R						
168	38:20.6	yeah	P	laughs,					

Figure C.21: Thematic analysis. Participant 7, part 5.

Time Code	Comment	Per son	Action	Topic phase 2 (main)	Topic phase 2 (sub)	Description /code phase 3	Thematic map 1) phase 4
1							
2	01:54.3 So this is the cue sheet (cs) and time-line (tl)	R					
3	01:55.7 So, you had got a.. 2 Ti here, which when you've got your sounds it will give you some count up to suggestions in these areas, so you kind of have point CS? and you can play them but at the moment suggestions (point to Ti) and you can play them but at the moment the sounds are for the point of the experiment so they demonstrate how the system works rather than actually being.	P		3 1,2		understanding concept	communicating and tool support
4	02:23.2 I see, the right sounds	P					
5	02:24.6 accurately mapped, they kind of are but not very well	R					
6	02:26.3 I see, but this is what you want to find out later on what kind of sounds people want to use?	P					
7	03:31.2 yeah, but at the moment I am looking at the method construction	R					
8	03:32.3 yeah, but at the moment I am looking at the method construction	P					
9	03:32.5 and the steps and whether ..what order you do things in and feedback and..	R					
10	03:39.5 yeah	P					
11	03:39.5 things like that	R					
12	03:42.8 yeah, OK so ..'basing your response on the written scenario you are required to fill out columns 2 to 5 of the cue sheet' .. ah , ok? sorry Doon, do I (goes to Ti) have to listen to the sounds	P		3	1,2	Confusion over task	confusion
13	03:45.2 no you don't have to, so I if you do the first bit list in the CS. If you start, when you start to fill in columns 6-12 you will see what happens to the timeline and you might have a clearer idea	R					
14	03:39.7 sorry, I'm really confused what do I do first?	P		3	1,2	Confusion over task. Has also looked at interfaces so these aren't helping	confusion
15	03:42.1 so, you fill in columns 2-5	R		3		researcher has to explain	
16	03:45.3 these ones? (points at correct columns)	P		3			
17	03:45.3 so you have got your events here, have you seen this? (1). So you have got your event 1 . So fill in this one first (2) which is your overall interface design so, on your scenario here, 'engaged in other activities monitoring electricity as a background activity', so .. have a look and see (3)	R	(1) point to written scenario (2), show coils 1-5, (3) show her drop down from col 2	3	1	1 researcher has to explain	confusion, study design, communicating
18	04:15.9 and I do that, one for each event?	P		3	1	1 beginning to understand	
19	04:15.9 yeah so you do this and then you do event one which is here (1) , 6 to 12 and the you will get there and then you will do event 2	R	(1)point to scenario	3	1	1 researcher has to explain	
20	04:27.5 OK so these ones (points to coils 1-5)) are applied to both events	P		3	1	1 understand that top half of CS is for general user/interface req.	
21	04:38.6 yup its the overall	R				understands	
22	04:31.1 I see, interface yeah	P		3		wanted to choose multiple options for context	
23	04:39.4 (looks at col. 2) what if I've got more than one answer? can't do that can I so I've got to choose its like but I don't work	R		3	1	1 researcher has to explain	
24	04:47.7 yeah, I guess, I mean I ..most people would think this was home but then I will know that maybe having more is a good thing	P					
25	04:57.6 yeah I guess, I mean I ..most people would think this was home but it could equally be work, so it would be nice to be able to click more that one if that doesn't make it more difficult ? which it does but...	R					
26	05:14.2 (looks at col. 3) or, the listening mode is 'passive, active, a mix.. a mixture' what do you mean by that?	P		3	1	1 understanding	
27	05:21.6 it's because I said they are using audio while they are doing other tasks, so thats classified as sort of passive mode, but if you don't know you don't know its fine. its good .. I need to know what level to pitch this at	R				1 demonstrating that I intend to decipher who to pitch this at. listening mode is potentially confusing	
28	05:39.9 yeah, I guess if..I thought that but I then I thought, I would rather ask you because I wasn't sure about it. umm, I guess . Do you want me to tell me your answers to this	P		3	1	1 wanted help as re-assurance	
29	05:54.6 if you want to	R					
30	05:54.6 um, well I said a mixture because yeah thats what , I mean theres two- one event is more active and the over is more passive so...	P		3	1	1 rationale for choosing listening mode is good and logical	understand requirements after explanation
31	06:13.7 Theme; is that the visual appearance?	R					
32	06:20.7 that would be the sort of audio one really. So that would be, ? yeah the audio interface if you wanted an overall theme to the sounds ? it might be too abstract	P		3	1	1 understands its role. But make it visual as opposed to audio	

Figure C.22: Thematic analysis. Participant 8, part 1.

33	0613.3	I would take, I mean the word, skin doesn't say anything to me so	P			3	1		screen saver, not far off	terminology
34	0616.1	...it just sounds like a screen-saver	P						what - skin means	
35	0616.2	...yeah, yes, that (1) could be all sorts of ... I mean probably	R							
36	0614.6	thats something that people want to be able to change right	P			3,5	1		idea of changing your mind and designer, personalising	
37	0710.1	yeah exactly you can personalise the interface is the idea	R							
38	0710.4	so I will put travel because thats why I want to do now, which	P							
39	0718.3	in a really time and so maybe I should put that (1) when the	P							
40	0718.3	user turns the system ?' I guess again that could be 2 different	P							
41	0718.3	states but I would say the user turns it on	P							
42	0719.7	I think what I find confusing about the instructions is that it says	P							
43	0719.7	hearing your responses' which tells me that I have to write down my	P							
44	0719.7	responses to what I say something about steps). Exactly I think thats why I	P							
45	0719.7	was confused at the beginning because I didn't understand what	P							
46	0811.4	responses you meant	R							
47	0811.4	yeah, did I respond already and then go through this	R							
48	0817.3	...yeah, my thoughts. Maybe just	R							
49	0817.3	just put thoughts. Yeah I think that would make sense	P							
50	0818.2	(1) ok 'classify the information. what is the information that needs	P							
51	0818.2	to be represented through audio?' er, do I need, sorry, do I need	P							
52	0818.2	to type something in this	P							
53	0819.3	if you want to, yes	R							
54	0819.3	ok, so where it says text one word, so I just give it word that	P							
55	0910.6	what you think you want to represent through audio	R							
56	0910.6	ok, probably .. because this is event 1 its really 2 events isn't it	P							
57	0910.6	one, you turn it on and then the 2nd one its steady, so its kind of	P							
58	0912.3	2 different things - I think	R							
59	0912.3	no, you're right. The previous participant just observed that too	R							
60	0916.4	yeah, because its 2 different, you would describe it two different	P							
61	0916.4	.. because you would like have 1 sound when it turns on and then	P							
62	0916.4	another sound when it turns off, so its steady, but its	P							
63	0916.4	also an event by itself (1). So I just do a switch on now	P							
64	1013.1	thats fine. The fact that your talking is more helpful	R							
65	1018.1	um, 'identify as an environment/location, object, character' - is	P							
66	1018.1	that on a '...' an object, character' ..what do you mean by that?	P							
67	1024.1	its abstract. I mean I just wondered if you could identify one of	R							
68	1024.1	the things that you're talking about	R							
69	1025.7	im just trying to understand what you mean with, 'an environment or	P							
70	1025.7	location', ? like it switches on and something is happening and how	P							
71	1025.7	do I identify that what is hap? so lets say I switch it on and it	P							
72	1034.4	yeah, well ..because your beep will be telling you something about	R							
73	1034.4	something so there will be a thing, what is it you're wanting to	P							
74	1034.4	know about, so	P							
75	1034.4	yeah	R							
76	1034.4	electricity	R							
77	1034.4	yeah	R							
78	1034.4	as a certain thing, could you help with the sound design?	P							
79	1116.1	are you ..mean something extra? to the sound?	P							
80	1117.3	yeah, so or to ..to help the properties of the sound, so to help	P							
81	1117.3	decipher how you might go about sonifying it, so electricity - if	P							
82	1117.3	you think a out a cartoon or something, if you had like	P							
83	1117.3	electricity, how would you? ..what would it sound like? Which is	P							
84	1117.3	very surreal, but you know, someone has made that decision	P							
85	1117.3	the sound	P							
86	1210.8	yeah ok..so I've put in object	P							
87	1210.8	(1) (2) if I change that do these automatically change as well?	P							
88	1210.8	yeah, its just ..to help with the filtering	P							
89	1217.1	ok, but its not suggesting that because I have chosen object..i now	P							
90	1217.1	have to choose man-made?	P							
91	1217.1	yeah, its just ..to help with the filtering	P							
92	1217.1	have to choose man-made?	P							
93	1217.1	yeah, its just ..to help with the filtering	P							
94	1217.1	have to choose man-made?	P							
95	1217.1	yeah, its just ..to help with the filtering	P							
96	1217.1	have to choose man-made?	P							
97	1217.1	yeah, its just ..to help with the filtering	P							
98	1217.1	have to choose man-made?	P							
99	1217.1	yeah, its just ..to help with the filtering	P							
100	1217.1	have to choose man-made?	P							
101	1217.1	yeah, its just ..to help with the filtering	P							
102	1217.1	have to choose man-made?	P							
103	1217.1	yeah, its just ..to help with the filtering	P							
104	1217.1	have to choose man-made?	P							
105	1217.1	yeah, its just ..to help with the filtering	P							
106	1217.1	have to choose man-made?	P							
107	1217.1	yeah, its just ..to help with the filtering	P							
108	1217.1	have to choose man-made?	P							
109	1217.1	yeah, its just ..to help with the filtering	P							
110	1217.1	have to choose man-made?	P							
111	1217.1	yeah, its just ..to help with the filtering	P							
112	1217.1	have to choose man-made?	P							
113	1217.1	yeah, its just ..to help with the filtering	P							
114	1217.1	have to choose man-made?	P							
115	1217.1	yeah, its just ..to help with the filtering	P							
116	1217.1	have to choose man-made?	P							
117	1217.1	yeah, its just ..to help with the filtering	P							
118	1217.1	have to choose man-made?	P							
119	1217.1	yeah, its just ..to help with the filtering	P							
120	1217.1	have to choose man-made?	P							
121	1217.1	yeah, its just ..to help with the filtering	P							
122	1217.1	have to choose man-made?	P							
123	1217.1	yeah, its just ..to help with the filtering	P							
124	1217.1	have to choose man-made?	P							
125	1217.1	yeah, its just ..to help with the filtering	P							
126	1217.1	have to choose man-made?	P							
127	1217.1	yeah, its just ..to help with the filtering	P							
128	1217.1	have to choose man-made?	P							
129	1217.1	yeah, its just ..to help with the filtering	P							
130	1217.1	have to choose man-made?	P							
131	1217.1	yeah, its just ..to help with the filtering	P							
132	1217.1	have to choose man-made?	P							
133	1217.1	yeah, its just ..to help with the filtering	P							
134	1217.1	have to choose man-made?	P							
135	1217.1	yeah, its just ..to help with the filtering	P							
136	1217.1	have to choose man-made?	P							
137	1217.1	yeah, its just ..to help with the filtering	P							
138	1217.1	have to choose man-made?	P							
139	1217.1	yeah, its just ..to help with the filtering	P							
140	1217.1	have to choose man-made?	P							
141	1217.1	yeah, its just ..to help with the filtering	P							
142	1217.1	have to choose man-made?	P							
143	1217.1	yeah, its just ..to help with the filtering	P							
144	1217.1	have to choose man-made?	P							
145	1217.1	yeah, its just ..to help with the filtering	P							
146	1217.1	have to choose man-made?	P							
147	1217.1	yeah, its just ..to help with the filtering	P							
148	1217.1	have to choose man-made?	P							
149	1217.1	yeah, its just ..to help with the filtering	P							
150	1217.1	have to choose man-made?	P							
151	1217.1	yeah, its just ..to help with the filtering	P							
152	1217.1	have to choose man-made?	P							
153	1217.1	yeah, its just ..to help with the filtering	P							
154	1217.1	have to choose man-made?	P							
155	1217.1	yeah, its just ..to help with the filtering	P							
156	1217.1	have to choose man-made?	P							
157	1217.1	yeah, its just ..to help with the filtering	P							
158	1217.1	have to choose man-made?	P							
159	1217.1	yeah, its just ..to help with the filtering	P							
160	1217.1	have to choose man-made?	P							
161	1217.1	yeah, its just ..to help with the filtering	P							
162	1217.1	have to choose man-made?	P							
163	1217.1	yeah, its just ..to help with the filtering	P							
164	1217.1	have to choose man-made?	P							
165	1217.1	yeah, its just ..to help with the filtering	P							
166	1217.1	have to choose man-made?	P							
167	1217.1	yeah, its just ..to help with the filtering	P							
168	1217.1	have to choose man-made?	P							
169	1217.1	yeah, its just ..to help with the filtering	P							
170	1217.1	have to choose man-made?	P							
171	1217.1	yeah, its just ..to help with the filtering	P							

Figure C.23: Thematic analysis. Participant 8, part 2.



72	13:21.4	yeah maybe	P		4.5	1.3		see above	
73	13:22.6	no, thats exactly it because the context is important when designing these things so its to get you to think like that	R		2,3,5			They arent sound designy	
74	13:30.2	so i will leave it with wood, its a bit traditional but	P						
75	13:33.6	(1) 'what do you want the audio to communicate' .. yeah, some of these words are really like sound-designy and i have heard them, but i don't really know what they mean	P	(1) looks at col 8	1,3			terminology	
76	13:55.0	like what which ones?	R					see above	
77	13:56.0	like .. sound colour.. i've got an idea but i don't know if thats really what you mean?	P		3	1,3		not meant to be a sound related word as such, more a property of the information	terminology
78	14:08.7	its funny because you're thinking about it from a sound design, .. like your'e thinking 'oh this has all got to make the sound' .. you're aware that obviously that this going to affect the sound and you've got that haven't you?	R						
79	14:08.7	[yeah]	P						
80	14:08.7	but this is to do with the properties of what it is that you want to know about, so you'd want to know about ..say you were sonifying.. i don't know, rainfall or something, you would want to know about maybe volume - like how much rain has fallen, so that 's a property of the ..or the science of the thing	P						
81	14:39.9	i see, so this is actually related to the switching on .. ok, .. but .. what's the sound about the types of sounds as well?	R						
82	14:53.9	because you're already stop .. need in your head, going..what colour does that make it (both laugh)	R		1,3	1,3		see above	
83	15:05.6	ok, mm now that i have chosen natural and wood maybe? what does velocity mean again? speeding up isn't it, like acceleration or so, maybe that would be nice	P						
84	15:35.3	(1) 'what does the information do at this point in the scenario?' the object, moves up because you switch it on	P	(1) looks at col19:					
85	15:51.8	(1) 'The sound is .. discrete' .. again this is the first scenario of the 2 events- the switching on because when it stays constant, when it stays it should stay constant so	P	(1) looks at col 10:	3	1,3		Recognises that 2 events not one. Event clarity	study design
86	16:08.3	righter, so you split event 1 into 2?	R						
87	16:10.3	yeah	P					see above	
88	16:10.9	OK	R		3	1,3			
89	16:15.4	OK .. the behaviour can be seen as positive, i guess	P	(1) looks at col 11:					
90	16:21.6	(1) 'the sound, stops, repeats, stops, changes/changes due to an' .. what does changes due to a non-resolution mean? ..oh because its not resolved ok	P	(1) looks at col 12:					
91	16:33.3	so it switches on and then it switches off is that what stops means?	P						
92	16:48.6	yeah, so say it might be that in one of your use-cases your sound suddenly stopped, .. but it doesn't in this case	R						
93	16:58.5	its the switching on moment so it would stop, it would just indicate i switched on now	P						
94	17:06.0	or, yeah i mean it could be yes	R	col 12 menu 2:					
95	17:10.2	(1) 'what causes this' ..the system i guess. OK so now its the 2nd event.	P						
96	17:18.7	which is event 1 for you is it? you split the first one into 2 or?	R		3	1		see above. Changes it according to study even though sees it as 2 events	study design
97	17:26.7	oh, no i thought i just gonna continue	P						
98	17:31.1	oh good i thought you had split	R					see above	
99	17:32.1	oh yeah, no i just took the 1st event - i did split that in t2 - but .. i think the 2nd event is the one i ignored the steady one, although i quite like that scenario but	P		3	1			
100	17:48.0	its good to know though, there could be more events	R					event splitting up further	
101	17:51.7	electricity use goes over a desirable threshold and then the user turns the monitoring system off' ..so again this is 2 scenarios [events], so i'm just taking the first one -the electricity being used goes over a desirable threshold	P		3	1		see above.. Further 2 events. So 4 in total	study design
102	18:10.6	and turning off being another event?, yeah OK thats fine	R						
103	18:15.6	its basically, i mean the turning off is the opposite of the turning on event so you could 'just, you know..its discrete but its negative ..type of thing	P					on/off as binary events	
104	18:27.5	so the electricity being used goes over a desirable threshold' so its kind of an alarm right? ..(1)	P	types Alarm into e2, text box, col 6	6	1,3		identifying as an alarm	
105	18:40.1	(1)..so an object, jumping to your face ..its weird because in this case i would say character in a way	P	e2: col 6 menu 2	3,4	1,3		adds a characterisation to it because of the action /requirement.	
106	18:53.8	(1) (2) .. or maybe not a character (3) . Lets keep it with an object is thats alright? im a designer i want things consistent (4)	P	e2: col17, menu 1, looks back to col 6 menu 2-	3,4	1,3		Chooses character but because of filtering options stuck with object sharp for an alarm	terminology
107	19:10.3	(1)st like that you have got concrete in there (2) i will choose that but don't know if it makes sense? doesn't does it, maybe metal. because you want something sharp for an alarm	P	e2 col 7 menu 2, laughs	2,4	1			
108	19:49.4	(1) so you would probably get the mass or amount ?so amount	P	e2 col 8:					

Figure C.24: Thematic analysis. Participant 8, part 3.

109	20:05.7	(1) the object moves up, i guess, (2), the sound is discrete	P	e2 col 9+, col 10					
110	20:23.3	(1)'the themes is?' that's difficult because positive, i mean obviously it resembles something negative but the behaviour is positive because its accelerating	P	e2, col 11:	3	1		2 different means of the term positive. Terminology	
111	20:44.4	going up . Yeah, where it was positive in that its a rise or a plus exactly, yeah . So i will put positive because thats the way i would understand it	R						
112	20:54.1	(1), yeah and then it changes due to an increase,(2): this is caused by the system	P	e2 col12 menu 1 selects opt 4, menu 2					
113	21:04.8	(1), yeah and then it changes due to an increase,(2): this is caused by the system	P					understanding after seeing	tool support
114	21:17.4	is that it?	R		3	1,2		TL	
115	21:20.7	so i will show you now. So the was that you had your events and you had your context, and then its put (2) your events on timeline so you can kind of look at your scene	R	CS, go to TL					
116	21:20.7	oh i see	P					understanding after audio	
117	21:20.7	or sound design suggestions based on what you put and then in theory each sound you would be able to play your different sounds and go 'oh thats the sound of event 1 (1), sound of event 2 (2) and this is how they blend together (3) . And you can look at how the sounds, how you can transition from one sound to the next	R	(1)point to it on TL, (2)show TL, (3) point to transition on TL				researcher explaining	
118	21:20.7	[mhm, yeah that the other..]	P						
119	21:20.7	so you have got (1) its the sound of electricity . But if its sound of electricity on that you have got (2) its subtle that kind of thing and you have a negative one (3) , its subtle	R	(1) play sample 3, (2) play sample 9, (3) play sample 8					
120	21:25.0	i like that, thats good with sound design	P		4	1		good likes the idea. After hearing audio.	audio in the process
121	21:27.3	(1) so the idea is that in theory now as a designer you can go 'oh right, so i have designed this sound an this is what they're suggesting and thats because of this' (2). So if i had a different scenario or wanted to sonify different property i could start to think about what else might affect the sound	R	(1) play sample 9, (2) show CS				researcher explaining	
122	21:27.3	[i see yes]	P						learning
123	21:10.7	thats is really clever doon, its really good i like that, its really good	P		4			good and clever likes principle	
124	21:17.8	its not obviously , the mapping, you know this is all mocked up at the moment	R						
125	21:30.9	(1) sorry. (2). [3] OK so these ones are not connected to what i have actually chosen ?	P	(1) plays samples 1,2,3,4 (2) laughs, (3) play sample 6				realised now or expected them to be and not what expected?	
126	21:33.1	not directly only the rise and fall was. It was just to give an example of how the method worked and what the idea of this is that you will be able to play the sounds and go 'oh, yuck' and go back to you your case and move it around	R						
127	21:33.3	[yeah]	P						
128	21:33.3	and start to get an idea of ?. as an interaction designer who perhaps isn't..hasn't got experience with audio, or that much experience .. can go 'oh ok, ...	R						
129	21:58.4	its nice, its very fluid i like that , yeah, no its really cool	P		4,5	1,2,3		likes fluidity-integration?	
130	24:02.3	thats nice to hear	R						
131	24:02.3	yeah, no its great	P		4				
132	24:02.3	thank you	R						
133	24:02.3	(1) i think what was the, i got the hang of it after a while but i think i was a bit confused about the sound design	P		3			time to learn	learning
134	25:03.1	the 'skin' that was tricky and i was thinking its maybe its because when you approach it there is like nothing on there and maybe if you give people an example	R		3			example to help	learning

Figure C.25: Thematic analysis. Participant 8, part 4.

137	25:03.1	[yeah, its a good idea]	R							
137	25:03.1	it would make more sense	P							
138	25:40.2	I found classifying the information' ?[...] yeah that was a tricky one. You need to be an abstract thinker to understand what you mean, which i am but	P		3	1		abstract terminology classifying the info	terminology	
139	26:32.6	Its like the longer you do it the more you understand'	P		3			time to learn	learning	
140	26:37.9	yeah, of course. People generally are quicker at event 2 as well because they have got the hang of it, which is why i did the screen capture	R							
141	26:47.6	themes'- yeah that was a bit confusing	P		3	1		confused by themes	terminology	
142	27:26.4	yeah , but thats a bit neutral its a bit difficult to say so i just.	P							
143	27:32.0	its fine the most important thing is your feedback (?) and the talking , this is	R							
144	28:26.0	So how i understand whats happening? i think it could be clearer. I'll put this ..its like, i just mean from the er, ..from the interface - the visual interface . Like if you pool [pull?]?because there is a lot of information on small space. Maybe its better as bullet points or something	P	answering SUS	3	1,2		interface, ideas for presenting the information	interface	
145	29:27.7	i think i would like to use this system ..i would love to	P					love to use it again		
146	29:33.1	i found this system unnecessarily complex? nah'. I think complexity is good	P	Brooke's	3				learning?	
147	29:40.8	i thought this system was easy to use? really, yes so i will just put 2	P							
148	29:49.7	'I think i would need the help of a technical person to be able to use this system'. if it was a bit better laid out, no i don't think so ..so i will just put 2	P							
149	30:04.3	' i found the various functions in this system were very well integrated ' ..what do you mean with that?	P							
150	30:10.3	perhaps I mean? uh how they kind of relate to each other maybe , so the jumps between the different parts of the interface	R							
151	30:25.0	ok, i think i am neutral about that	P							
152	30:29.9	' thought there was too much inconsistency in the system ', i don't really know to be honest	P							
153	30:38.4	i imagine that most people would learn to use this system very quickly'..yeah if its, like laid out a little bit better then , yes	P		3	1,2		quick to learn if interface was better laid out	learning, interface, tool support	
154	30:45.6	so you think the actual sort of method is fine its the b...	R							
155	30:48.7	yeah	P							
156	30:49.2	bit of interface which you	P							
157	30:49.2	totally ..yeah, yeah, yeah so i just give it 3 as well. No i think its really, can be really really intuitive, ..but yeah it needs a different ... i don't know if its the visual interface that needs to be different	P		3	1,2		intuitive but interface needs changing	interface	
158	31:06.2	yeah,, because the visual interface is me trying to [implement?] a method if that makes sense , so its not fit is the interface because thats an important part of the accessibility of the method, but i'm not goig to produce a really shiny piece of software at the end of this, its about the steps behind it... So its kind of important , its hard its a balance	R							

Figure C.26: Thematic analysis. Participant 8, part 5.

159	31:06.2	[yeah, ok]	P							
160	31:24.3	yeah, but i like it because i think its very playful ? but useful as well	P		3,4	1,2	1,2,3	playful but useful. Could be method/interface or impact of both	playful/enjoyment	
161	31:30.4	thats really nice, thats good word	R							
162	31:31.9	'i found the system very cumbersome to use', whats does cumbersome mean, thats like really..	P					understanding evaluation.Terminology of Questionnaire	terminology	
163	31:35.9	clumsy and heavy -not intuitive i guess	P							
164	31:41.9	I will leave it with neutral as well because the things that i have got t criticise is the just the way its laid out so its not your system	P		3	1,2		interface and not system / method per-se. "just the way its laid out, not your system"	interface	
165	31:51.5	i felt very confident '..yeah i got pretty confident at the end	P		3			time, learning more confidence		
166	32:00.2	' i need to learn a lot before i could get going'?yeah i will leave that with neutral	P							
167	32:13.8	Do you have any thoughts about other scenarios?	R	**other scenarios**						
168	32:13.8	everything (i) just like ..well its probably not very good for, like you car i would see it as a bit dangerous maybe	P	laughs	6			dangerous cos distracting to use or that audio is not suitable for this scenario?		
169	32:23.9	what having audio in your car when you..	R							
170	32:26.2	yeah its like maybe not, maybe it would be , nah, i don't know . But its like i want my coffee machine, i want my alarm clock , i want my ..i want anything in the home	P		6			home-based applications/ context		
171	33:03.4	its feels a bit, it feels quite personal so i'm not sure if i would bring it out of the confined space - so maybe it doesn't work for 'work' . But yeah it would be different at work	P		6			feels personal		
172	33:20.4	which i guess is maybe.. that would be theme . i guess i could put a filter on that so the sounds kind of..you know, maybe at home you might have a certain type of sound design	R							
173	33:20.4	[yeah]	P							
174	33:20.4	or for work..	R							
175	33:30.9	or it might be questions about, more questions about the context	R							
176	33:35.2	mm, i remember that 'scanner' the guy who [supervises an astrid??] he once told me that he made sound design for a lamp . i think it was Phillips , but yeah, maybe you can find out . i think it was a bit cheesy but ? i think it was a lamp that was an alarm clock as well	P							
177	34:08.3	ummm, i just want it now, so i'm thinking about where else can i have it .. no i think its, yeah, its good in the home	P		4,6			"I just want it now". Good in the home		

Figure C.27: Thematic analysis. Participant 8, part 6.

	Time Code	Comment	person	Action	Time Frame	Topic phase 2 (main)	Topic phase 2 (sub)	Topic phase 2 (sub)	Description /code phase 3	(Thematic map 1) phase 4
1										
2	0.05	so 1st reaction is oh [...] too much information, what should I do	P		0-1	3	1		immediatley interface puts her off	interface
3	0.12	OK and then user interface	P		0-1					
4	0.4	first reaction is im a little bit overwhelmed	P		0-1	3	1			
5	0.44	and it seems bit complicated	P		0-1	3				
6	0.54	so the scenario is made up of 2 events. Ok so I can see events in pink, that's good.	P		0-1	3	2		identifies colour relating to events	interface, layout
7										
8	2.4	so why do you separate 2-5 and 6-12	P	reading out instructions	0-1					
9	2.45	Because 6-12 is event 1, and then 6-12 is event 2	R		2-3					
10	2.5	Right, ok so wasn't clear to me. Which was event one and which was event 2	P		2-3	3	1		confusion over layout	interface
11	2.5		P	reading out instructions	2-3				task confusion	
12	4.17	Ok, errr, I don't know what to do to be honest	P	moves mouse to C3	4-5	3	1			
13	4.22	wait wait wait, I want to figure it out	P		4-5					
14	4.25	so, I have time. I don't know if I should press time, the start?	P	moves mouse to time column	4-5	3	1		not realting instructions to tasks	learning, study design
15	4.3	I have context	P		4-5					
16	4.5	context, so do I choose a context?	P	looks at menu options	5-6	3	1			
17	5	I do how do I know that?	P		5-6	3	1		not realting instructions to tasks	learning, study design
18	5.04	2 to 5	R		5-6					
19	5.06	ah 2 to 5, yeah	P		5-6					
20	5.16	so the scenario is for the 1st one,	P		5-6					
21	5.18	yeah so you've got what the monitring does and then you have got your example of a use-case so someone using it. Based on this information, these events fill it out the best you can. There is no right or wrong	R		5-6				researcher explaining	
22										
23	5.35	yeah yeah ok	P							
24	5.4	so this is my monitor	P	looks at col 6 menu	5-6					
25	5.57	OK, so I have "home"	P	selects home	5-6					
26	6.01	sport', actually sport	P	selects sport	6-7					
27	6.07	listening. Im listening	P	looks at menu options	6-7					
28	6.11	Active listening to the sport	P	selects active	6-7					
29	6.13	whats a mixture?	P	looks at listening menu	6-7	3	1		doesn't understand mixture - terminology	terminology
30	6.3	Actually I going to listen passive because im doing sports. In the background so passive	P	selects passive	6-7	3	1		realites listning to activity involved in. Designing for user and context	terminology
31	6.38	Then theme is energy. Use do sport	P	looks at theme menu. selects energy	6-7	3,4	1		energy related to support. Shows diversity in association. And how this can change given context	terminology
32	6.44	And then interaction, 'The sound is 1st effected when the user turns it on'	P	selects user turns it on from column 5	6-7					
33	7.01	OK, so then we have the 1st event	P	moves mouse to event 1	7-8					
34	7.05	'what is the information that needs to be represented through audio?'	P	reading out scenario	7-8					
35	7.25	erm, I don't want any information. Event, I have an event, I have a system, electricity. So the event is steady.	P	enters steady	7-8				possible confusion between information and event?	
36	8.01	identify as... errr, errr	P	looks at col 6 menu	8-9					
37	8.19	steady', 'electricity steady.. An object?	P	looks at col 6 menu. Selects object	8-9					
38	8.25	Not sure about that though	P	moves to col 7.	8-9	3	1		Not sure about object as a option for classification	terminology
39	8.35	Right,	P	reads scenario	8-9					
40	8.55	'properties of the object, location or character'	P	reads text in col. 7	8-9					
41	9.04	manmade. 'my event is user turns system on and electricity use is consistent for some time'	P		9-10					
42	9.15	so this object, electricity. Im going ot go manmade	P	selects manmade	9-10					
43	9.3	characterise electricity.. 'steady'.. But if its water it cannot be made from man	P	looks at menu options	9-10					
44	9.44	'electric'	P	selects electric	9-10					
45	9.5	'what do you want the audio to communicate'	P	reads text in col 8	9-10					
46	10	I want to communicate (1)	P	(1)looks at menu options	10-11					
47	10.05	steadiness so its steady so it should be... it should not commincate motion, it should commincate some kind of steady motion	P	selects motion	10-11					
48	10.3	Behaviour. 'What does the information do at tis point in the scenario?'	P	moves to col 8 and reads text	10-11					
49	10.4	information...remains steady	P	selects remains steady	10-11					
50	10.45	occurance in relatoin to... its constant	P	moves to col 10. reads text. Selects constant	10-11					
51	11	Themes... its neutral	P	looks at col 11 and menu	11-12					

Figure C.28: Thematic analysis. Participant 9, part 1.

52	11.06	Does the information/data change?	p	moves to col 12 reads text	11-12						
53	11.11	err no, it doesn't change but there is no..?	p	looking at menu options	11-12						
54	11.19		p	reads at options in menu	11-12						
	11.27	But I want to change. Doesn't change. Steady so it doesn't change	p	selects repeats	11-12						
55	11.45	what causes this?	p	moves to menu 2 col 12.	11-12						
56	12.05	what causes the..what, change?	p	looking at menu options, reads them out	12-13						
57	12.11	Im confused here. This is caused by the user	p	selects user	12-13	3	1		confused about triggers	terminology	
58	12.2	does the information, does it change. So this is the information /data?	p	goes back to text above menu one in col 12.	12-13						
59	12.3	caused by the system because it says its consistent for some time? I guess then it changes	p	looks at menu 2 again	12-13						
60	12.35	Ok, so event 2	p	selects system	12-13						
61	12.5	Ok, so the word is... what is threshold exactly?	p	reads scenario	12-13						
62	13.05	a set limit, so a point that you have marked as being	R	col 6 menu 1	13-14	3	1		threshold. Could be terminology confusion	terminology	
63	13.15	its not positive or negative its just a	P		13-14						
64	13.35	well it's a desirable threshold so I guess	R		13-14				leading, desirable-positive?		
65	13.36	Oh is desirable so positive, OK	P		13-14						
66	13.48	so, because its desirable the word communicated should be positive	P		13-14						
67	14.03	"ready", something like that	p	writes Ready	14-15						
68	14.1	identify as a character	p	moves to menu 2,	14-15						
69	14.18	it is, that one	p	col 7 menu 1, selects human	14-15						
70	14.3	'inner world, outer world', I don't get this. I don't get what inner and outer	p	looks at col 7 menu 2	14-15						
71	14.45		p	selects inner world	14-15						
72	14.48	what do you want the audio to communicate	p	moves to col 8 and reads text	14-15						
73	14.55	err, action	p	selects action	14-15						
74	14.58	what does the information do at this point in the scenario?	p	moves to col 9 and reads text	14-15						
75	15.11	performs an action	p	selects performs an action	15-16						
76	15.15	in relation to.. Discrete	p	moves to col 10 and reads text. Selects	15-16						
77	15.26	its positive	p	moves to col 11 and reads. Selects positive	15-16						
78	15.35		p	moves to col 12 reads text	15-16						
79	15.39	ah so transition into next event	p		15-16						
80	15.5	does the information change? Yes it changes	p	looks at options in col 12 menu 1	15-16						
81	16.11	it changes. Stops	p	selects stops	16-17						
82	16.13	stops as well	p	changes col 10 stops as well	16-17						
83	16.17	err caused by the user	p	looks at col 12 menu 2. selects caused by the user	16-17						
84	16.3	so what's happened is you have gone through your senario and use case and its given you some suggestions on the TL here, so you can see your event 1 and its given you some sound design suggestions, event 2. And because this is a prototype at this point the idea would be that you can play these sounds and audition them. So you have got your use case with different events but you can move the sounds around, but your thinking about how the sounds might go together	R	show TL	16-17				researcher explaining		
85	17.04	so how the sounds go together	P		17-18	3	2	1,2	sees event relationships	comprehension, role support	
86	17.08	well this is badly done because its just an example, but say you have a positive one	R	open up samples	17-18						
87	17.15	that's rising slightly	R	plays example 9	17-18						
88	17.22	and if you had had steady negative	R	plays example 2	17-18						
89	17.27	its just to demonstrate that [...] you can map out your scenario and events and playback the sounds	R		17-18						
90	17.35	mm, mm mm	P		17-18				understanding after demonstration		
91	17.38	This is the method steps rather than... the next steps we will build sounds	R		17-18						
92	17.41	so from events you get design guidelines for your sound	P		17-18	3	1,2,3	1,2	links events to sound suggestions	comprehension, role support	
93	17.44	yeah, exactly and then some sound suggestions to help interaction design	R		17-18						
94	17.55	just wanted some, um (??) moved around on it in order to..	R		17-18						
95	18.07	how are we using design process, I found it confusing	P		18-19	3			found it (method/tool?) confusing		
96	18.1	OK this is good, I mean its not good but	R		18-19						
97	18.15	I found it confusing, I found it..	P		18-19	3					
98	18.18	ahh, sure...	R	hand her questionnaires	18-19						
99	18.24	Right I have done that its very hard to evaluate	R		18-19						

Figure C.29: Thematic analysis. Participant 9, part 2.

## Appendix D

# Study Three Tasks and Open-Ended Feedback

### D.1 Task 1

Information Sheet 1 (sent to the participant prior to participating in the study)

#### **Study.**

This is to introduce you to the research, the study and to the method that is under evaluation. More detail will be offered when you do the study. However, this serves as an introduction.

#### **Part One. (Recording number one.)**

This is a study to explore and evaluate a method that can be used to create auditory interfaces and auditory displays for the human-computer interface.

The focus of this project is on interfaces, which are audio only, as opposed to multimodal interfaces, which use audio alongside visuals, graphics, touch etc.

There is a growing need for auditory displays and audio-based interfaces for mobile and eyes-free contexts of use such as someone listening to changes in stock values on their phone, someone listening to a cooker while ironing or car engine diagnosis system (or fuel gauge) while driving. However, there are arguably a limited number of accessible methods for novice designers that support their creation.

The method has been created using principles and ideas from soundtrack composition. The reason for this is to attempt to lower the barriers to creating audio interfaces and

displays, demystify the use of sound in the interface, encourage creativity, and potentially lead to the production of more engaging/interesting interfaces.

For the research the practice and theory of soundtrack composition have been used to develop 2 things.

1. Firstly, a method for developing interfaces. This method consists of a series of steps, which the designer works through to produce an interface. It starts with a scenario, the situation to be designed for, and hopefully ends with an implementable interface design, which has some of the characteristics mentioned above.

The method is independent of any specific technology, the steps could be simply written down on paper carried out by filling in paper-based forms (for example).

2. The second thing that is being derived from soundtrack composition is a series of computer-based tools to support the method. Most methods these days have some kind of tool support, and this is the case here. The idea of the tools is to help make the method less abstract to the designer, to automate some tasks and so help the designer save some time, and to help keep track of information created during the design process. Another aspect that the tools can assist with is enabling the designer to browse a larger number of design possibilities when applying the method, or to suggest to the designer some design alternatives of which they may not have been aware. The aim of this study is to mainly evaluate the method, but some evaluation of the tools, as they stand to date, will also take place. It is important to understand the principle of what the tool supports and, more than anything, its potential.

## **Part 2**

The method

The method has several steps:

The first step involves analysing a scenario that involves someone using audio to interact with a piece of technology specifically, using audio to interact with and receive information about different events within the scenario.

This analysis therefore involves gathering requirements from the scenario by applying an event ontology, in order to identify what types of events the scenario is made up of as well as describing any features, behaviours and values that are central to the different events.

Tool support for step 1: A Cue Sheet has been designed to support this method step. The Cue sheet allows for the mapping out of these different events alongside the information about their content, values and behaviours. In turn this supports the potential of working with and keeping track of multiple events within the scenario.

The second step of the method involves viewing a suggested mapping between the individual events to sound parameters, sound structures and audio dimensions. The sound suggestion is based on the type of event they are and their features, behaviours and values (as identified in step 1).

Tool support for step 2: A database is being designed to support and automate this method step. The database makes suggestions for sound design principles and loads sound files that can be used to map to the event. The database helps in the comprehension of how the sound design ideas and audio files relate to form a bigger compositional structure.

The third step of the method involves being able to work with simple representations of the sounds and a timeline of the scenario and iteratively move and audition the sounds in order to check for masking (whereby one sound might affect the perception of another), consider aesthetics etc.

Tool support for step 3: An interactive timeline has been designed to support this method step. The timeline is presented as a simple rectangular interface and the events as simple coloured cubes. The mouse and the left and right buttons can be used to lengthen, play and move the events horizontally across the timeline.

The study will explore the method and the early-stage versions of the tools (cue sheet, database and timeline) will be used in this exploration.

## **Information Sheet 2 (Read and listened to during the study)**

Part 1: Recap and Overview (recording number 2) I have designed a method to help you create audio for use within the human-computer interface that is based on soundtrack composition. Soundtrack composition functions to smooth edits between shots, enhance on and off screen actions, represent objects and characters and themes, anchor meaning and affect emotion. Auditory displays also uses audio to provide continuity, enhance and represent actions, represent objects and characters and themes, anchor meaning and arguably affect emotion or the way that something should be interpreted.

This document will guide you through the method steps. Your challenge will then be to use this method to design a set of sounds for an interface.

Please note there are occasional uses of music terminology in the document, however, if you are not a musician, don't let these put you off, they are not essential to the understanding of what is going on and there is always a non-musical equivalent of any example.

### **Important Elements to the method**

1. Scenarios A scenario refers to the 'story' of someone using audio to interact with a piece of technology (i.e using an audio interface). Often, when designing for human-computer interaction, fictional users are created and use-case scenarios developed in



order to test a series of potential interaction events. A different use-case will present the same scenario but with a different ordering of interaction events.

2. Different Events The idea is that most scenarios can be broken down into different events using a simple event protocol. The events we have identified for use within our method are: User Action Events (UA) System Action Events (SA) Continuous Events (CE) Data Point Events (DP)

A bit about the Events, the terminology and how to identify them. User Action events refer to a direct action from a user upon the interface. For example, turning it on or off, dragging an icon, or opening a file, etc. Additionally user action events refer to those events that involve a user but not necessarily in direct interaction with the interface for example if someone sends an email or message (i.e one is received) or if someone turns something on remotely and this affects the display of audio within the interface. An example could be if whilst monitoring electricity use in the home through audio, someone turns on the TV and this increases the electricity usage, the change in which subsequently gets represented through sound.

System Action events refer to something that happens as a result of the system and that cannot directly be associated with an action from a user as such. An example might be a system crash or freeze or an automated event

Continuous event refers directly to the status of the system or to a time-based process. For example the process of downloading a file or monitoring a live feed

Data point events are also known as active values and refer to those specific definable values that trigger a change and as a result cause a change in the audio output. For example if whilst continuously monitoring the heat of a system, the temperature reaches a certain significant point (data point), that in turn affects the sound of the monitored temperature.

Using the Method: There are three basic stages to the method and the method steps can be iterated in that it will be possible to repeat method steps and switch between the steps. The three basic stages to the method are:

1. Stage 1: Requirements Gathering: This involves determining what events make up the scenario in question
2. Stage 2 Mapping: Mapping the events within the scenario to sound ideas
3. Stage 3 Auditioning and arranging: Listening to and arranging the events and their recommended sounds to make a completed auditory display for your interface

Tools: There are basic (early prototyped tools) to help you complete these method steps. However, these are under development and are there to support the method. The tools are:

1. A cue sheet: used to map out the events. Each event is set out from left to right on the cue sheet. One row = one event and one cell = one piece of information (albeit a property or a behaviour etc) about the event..
2. A Database: supports the Mapping of identified events to sound design ideas and suggestions and sound files.
3. A timeline: once they have been identified and designed the sound/event can be auditioned individually and moved about on the timeline. Clicking on the event will play the sound. Each type of sound /event has its own dedicated track on the timeline and can be re-located using the mouse.

Note the colour coordination between the cue sheet and timeline. The first occurrence of any event is green, the second occurrence is pink, the third occurrence is blue and the 4th occurrence is yellow. This is so that if you are moving the events about, you do not lose track of which event you are working with. Please note that in theory this method/tool can visualise multiple events and has the potential of supporting a designer in working with as many events as the scenario contains.

## **Part 2 (Recording number 3)**

Event to sound rationale. The information that gets gathered about the events gets mapped into the cue sheet. This includes information about what happens during the event, its type, its property or features, its behaviour or theme, its occurrence and how it transitions into the next event. i.e whether it triggers another event.

All of these are requirements that we consider should be important when deciding what sound to use to represent the event. These gathered requirements are therefore used to help guide a possible sound design idea for the event however, it is important to realise that this method offers guidance and should be used for inspiration.

For example, the database might suggest that a user action is represented through an everyday sound that can be associated with the action or a similar action. Alternatively, the database might suggest that a user action is represented through a musical sound and that if it's a negative action that a minor (or sad) chord be used to represent the action, for example. The context will play an important consideration when determining the sound as well; should, for example, the sound be loud in order to cut across other sounds from the context or should it be a sound that compliments existing sounds? Do you have a continuous event representing rising temperature? Does the temperature rise in your scenario and so does the sound need to rise as well in volume or pitch perhaps?

Overall, this should encourage you (the designer) to think about how the different events

might sound as part of an overall composition as a soundtrack for your scenario. The timeline helps this.

The Timeline: is somewhere that all the events can be simply mapped out and played back. The principle is to cater for different use case scenarios that might present different events in different orders. The idea is that these can be designed for using the timeline that allows the events to be moved and re-positioned.

### **Part 3 (recording 4)**

Filling out the cue sheet: I am now going to talk through an example of filling out the cue sheet. By using the scenario for reference, we start by identifying the different events within the scenario. The first task is to fill this information out onto the cue sheet, in an event-by-event, basis, by typing directly into the cells. The cue sheet is optionally filled out from left to right and from top to bottom. One row makes up one type of event and once cell contains one piece of information about the event.

Filling out events Now please look at this screen shot of the scenario window.

1. To start with we read the scenario to see if we can identify the different events that need to be represented through sound. Please note it is possible to type in this window or use pen paper etc. to make notes.
2. Once this is done, on an event-by event basis, we identify what happens in the event ie. What the action is. We then write this in as much or as little detail as you need into the first column of the cue sheet and the first cell of your event. The level of detail does not matter because the cue sheet is for your reference only and to help you map out the events and keep track of your design rationale during the design process.
3. Following this identify what type of event it is that you are designing. Is it a user action, a system action, a data point or a continuous event? We then check the appropriate box in the 2nd column of the cue sheet.
4. Moving onto the third column/cell we identify the context for the event, For example does the event happen outdoors, or indoors, or in a kitchen, or in a car etc. Also we need to consider and write down any other sounds or contextual features that might impact upon the audio.
5. Moving onto the 4th column/cell we describe the event in more detail. Is there a value we can assign to it if it is a data point event, is there a set value that it needs to be at, for example. Can we identify any keywords that relate to any properties that are being represented through audio for example if it is a continuous event is audio being used to monitor temperature, or distance, for example

6. In the 5th column we identify if there are any behaviours that we think can further help classify and describe your event. For example does the action rise or fall
7. In the 6th column we identify a theme for our event. For example is the action a good or a positive or a bad and negative thing. Is the continuous event happy or sad. Etc.
8. In the 7th column we identify whether it is the first occurrence of this event or whether this type of event has happened before. For example is it the first or 2nd user action in the scenario. Is the 1st, 2nd or 3rd system action, Is it the 4th data point etc.
9. Finally, we identify the transition , i.e. whether the event you are working with is responsible for triggering another event. Does the user action trigger a continuous event, or does a certain data point trigger a change in the continuous event or cause the user to turn the system off, for example.
10. For the sake of this study, once they are designed, events can be loaded onto the timeline using the buttons next to the cue sheet
11. The next step is then to move onto the designing the next event and so on. This is started on the next row down in the cue sheet

We will now load example 1 (see me) This is the scenario that has been designed. We will explore how the events have been mapped. Note that not every cell needs to be filled in, this is up to you. The cue sheet is to support your personal design choices and there are no right or wrong things to put in there.

You can audition the sounds by playing back the events on the timeline.

## **Part 4 (recording 5)**

The Database Explore the database by pressing the “open” button next to the database interface.

The content This database is working progress. The structure is outlined for you too look at: There are different categories and classifications for the sounds and a filter can be applied to help you choose a suitable sound. The Database in theory would automate the selection process and apply filters to your sound choices based on what you write in the cue sheet. However, for now this is written out for you to look at and some examples given.

Filters and Categories The filters and categories demonstrate how the information you enter into the cue sheet and the sound design suggestions map together. There are also other categories that can be selected to aid your design. For now there are a few written out examples of how this works. Please now look at the database

All of the available sounds have been categorised into ‘musical’, ‘Everyday’ and a ‘Mixture’. Following this further filters have been applied to categorise the sounds by the type

of sound they are and how they would get categorised for soundtrack composition. These include a Foley sound (an action sound), an isomorphic sound (whereby the shape of the sound matches the action), whether it forms a motif (a simple little melodic pattern that is likely to be remembered), background environmental/ambient sound musical background (underscore) sound.

Further filters are there to demonstrate the structure.

For this study, you can map sounds to the events by selecting the appropriate tag from the drop down menu. UA to map to a user action, SA to map to a system action, DP to map to a datapoint and CE to map to a continuous event,.

Holding your mouse over the sound will reveal metadata about its length, which will also give you some ideas of what event you would like to map it too.

It is important to understand the database is being developed. But please explore the categories that we have implemented for now.

## **Task 2**

Create an AD Press clear to clear the cue sheet. Refer to the print out of the scenario about the avalanche safety system. Read through the use case scenario. Please try and map out the events on the cue sheet, in the order they occur in the use case

If it helps I have identified 5 events within this scenario. Once you have done this then explore the database and timeline

## **Scenario 1.**

*SUMMARY: Back Country Access (BCA) is a leading manufacturer of avalanche safety products, including the Tracker 3 Avalanche Rescue Transceiver. The new sounds need to be perceived as fast clean and immediate.*

### **REQUIRED SOUNDS:**

1. Sound when beacon is turned on.
2. Sound when switching to search mode.
3. Sound when mode button is pushed down.
4. Sound when mode button is released.
5. A Transmit sound for the fine search whereby the distance indicator is used to locate the shortest distance to the victim.
6. Sound when unit turns off.

USER INTERFACE: UI steps can be changed for this project.

USE CASE 1. User turns the system on- this triggers the system into a continual fine search mode that remains until the user turns it off. During this continuous event a sound is heard to indicate that the victim is 10 meters away. The user then moves closer and a sound is heard to indicate that the user is 0m away. The user turns the system off

## D.2 Section 2. Open-Ended Responses

Question 1d: Comment on the usefulness of the method and method steps.

- P1: Based on my little knowledge and experience in AD design, I guess my participation was alright. I used the cue sheet, database and timeline (strictly) according to the instruction to complete a short audio clip for the scenario and found that the cue sheet was the most helpful material as it prevent getting lost and decreased confusion.
- P2: I think I got a bit confused between some of the categories, such as behaviours/themes and actions/values/keywords, and what would have to go into which text field. Also, I did leave quite a few of them empty if I remember correctly. I think one issue is that I am an extremely visual person. So, for example, if I have to design interaction I usually express myself and ideas visually in form of a story board and would so implicitly define the context, the action, and take notes of the themes. Thinking about it, this was for me personally maybe the biggest hurdle in using this part of the interface: that I cannot think and express myself creatively in a grid. However, I think this is something which I would be able to learn over time, and also probably to make my sound design ideas more explicit.
- P3: The interface and database were extremely useful. I think I would have appreciated the option to describe the actions, values and keywords more when I refer to it in 6 months time!
- P4: Regarding last point: would have given a higher score if there was a more complete database + the ability to do finer edits to the sound – maybe some integration with other database/audio editing software/platforms.
- P5: By context for the events, do you mean the mountain rescue scenario? I think this is a really interesting idea for designers who are not necessarily experienced with audio.
- P8: It would be nice if in the final version users were able to listen to the sounds while selecting them from the drop-down box. This would help selecting the sound a person had in mind for each event.

- P9: I didn't make use of all the features, since my scenario was quite technical
- P11 Identify the events and the database suggestion are extremely helpful, especially for the non-professional people with no experiences on sound track processing
- P12 Takes little time to get used to, may be very useful in Game development. Was quite fun overall

Question 2b: Please state in what ways your design did or did not benefit.

- P1: I was able to move most events in the timeline except the continuous status, which is only the disadvantage I found
- P2: It benefited from being able to move the events because it allowed me to hear them in the order they would occur.
- P3: I could check and confirm that I was happy with the chosen sound; and see how the particular sound fitted with the overall mix.
- P4: It was definitely an integral part of the process, however this was hampered by the very limited database / sound generation system.
- P5: It was really important, having visualised the scenario and sequence and duration of events, to be able to play it back and see if that matched what I had visualised. This is a method I would use for testing out what I had designed as I went.
- P8: If referring to 'being able to move the events in the timeline', then yes, i think it's useful as the user is in control of how long the whole thing is and play the sound of each event exactly when they want.
- P9: It gave benefits, but I wanted to have control on length of the samples for each case, and I wanted to be able to preview sounds in the database before loading them
- P10 (-)
- P11: always play back and check the result is necessary for me.

Question 3b: Please comment on your understanding of the different events.

- P1: The use of abbreviation (i.e. UA, SA, DP and CE) might fit well with the design interface but it wasn't helpful to me especially for DP because I wasn't clear with its full term.
- P2: It was very easy to understand what the different types of events stood for. In the example it was quite clear what the difference is but I wondered what would happen if an environmental state change, i.e. a data point event, triggered a continuous event

- P3: The event types were described well, and examples given in the context of a scenario. Very easy to understand
- P4: (-)
- P5: thought I understood UAE and SAE but then got confused when doing the scenario task. e.g. turning the system on is a user action, but the noise is a system noise acknowledging that it is now ready to use.
- P7: Essential information and well described in the instructions
- P9: In my scenario I was confused by turning on the system (action from the user) and system saying: "I have been turned on"
- P11: Those are simple concept and very common in everyday life. No difficulties to understand them.

Question 4b: Please comment on your response and give detail on any ideas you may have for the scenarios that this this method could cater for.

- P1: I prefer the scenario broken down in points/steps, instead of a paragraph because it is similar to events were put on the cue sheet. It would help me to think more and clearer about transitional sound too
- P2: I think quite a few scenarios could potentially be analysed using the method and some of the tools if not all. For example, it could be used for product sound design, such as designing the sound of a vacuum cleaner or car. However, what becomes clear thinking this through is that data point events refer to events related to a third (environmental) source (i.e. different from user and system), e.g. when vacuuming up crumbs or when it starts to rain on the windshield, and that it is not at all clear what continuous events stand for and are in relation to - they could be user generated (e.g. keeping the car at a certain speed) or a system state (e.g. vacuum cleaner running) and also be depending on an outside variable.
- P3: This tool (and database) could be used in the construction of audio for many scenarios. From adding the auditory icons to physical tools, software applications and remote analysis; also in training applications such as simulators.
- P4: Currently this works well for very simple systems with only a few modes of interaction. I can imagine this becoming much more difficult (or time consuming) to use when dealing with large possible combinations of events and contexts. The system would be very useful for systems with monolithical events, i.e. clear thresholds, triggers, modes, etc. But less good for interactions that are predominantly continuous, e.g. designing sonification of real-time gesture data.



- P5: The search analogy is a good one. Maybe medical monitoring equipment. In car navigation or collision avoidance? Hands free skiing guide to avoid rocks and advanced runs?
- P8: I think it's scalable to many scenarios, possibly everything that has at least a start and an end.
- P9: 5 scenarios - to use positive / negative and music or 3 scenarios - simpler to highlight differences
- P10: Cooking, jogging or any other forms of exercises.
- P11: I think any scenarios that are relevant with human-technology system communication could be analysed by this event ontology.

Question 5b: Please comment on your response and outline any ideas (you would you like to add to the database).

- P1: I would like to see the database arranged in categories as it would accelerate the design process
- P2: It would be easier if it was possible to listen to the sounds by clicking on them in the database (maybe have a loudspeaker icon or something to click on). Having to load the sounds to an event and then click on the timeline in order to hear it is a bit inconvenient. By then I usually had forgotten, which sound file I had selected in the first place. It might be personal preference, though, because I like to get an overview of what is available first. Also I would like to have something like a shopping basket in which I could drop sounds I like for later selection. This is at least what I did in Logic for the Sound Recording module - I would drag and drop sounds I liked and wanted to review onto empty tracks. In addition, I would have liked to be able to import sounds - I did not quite find what I wanted and what matched the sound idea I had in my head.
- P3: Once the system has been fully built, you could go 1 step further and automatically allocate sound samples according to the event type (using artificial intelligence).
- P4: - larger data base - user tagging - simple editing: envelopes, cropping, blending - (above could be achieved by integrating with a simple audio editor like audacity, audition, reaper, etc.) - synthesis as well as samples, where users can hook up synth parameters to data streams, especially for 'Continuous Events'
- P5: Sounds that are short but you can loop them for a duration, rather than having all continuous sounds designed to be long. E.g. system status represented by a continuous

unobtrusive low beep. Being able to change the contour of change for a continuous sound, a bit like you can drag the shape of a curved cross fade or automation in Logic.

- P6: I'd like to be able to add my own recordings and samples. it would benefit from a wider range initially too, but that's more tool related than method related.
- P7: When creating for the avalanche scenario I would like to have had a choice of more 'alarm' sounds for the data points.
- p8: I found there are too many sounds to choose from, that's probably a good thing once you know how to use the system, but as a 1st time user i found it a bit hard choosing from the selection. It would help maybe being able to hear the sounds when you click on the grouping list on the right hand side, or from the drop-down menu. That would help users familiarise with the sounds quicker.
- P9: More sounds, that can be easier to preview. Finer control on length of samples - Colours of event occurrence in the database, once loaded. Way to control if they are loaded or not, otherwise it's easy to get confused (or assign sample name in the timeline)
- P10: Put all details or items under the drop down menus and this will make users to choose what they want more easily
- P11: it would be more efficient to listen to the samples in the database without the next step of adding them to the timeline.
- P12: It might be useful to have more different system switch on/of sounds
- P13: prehear the sound before load it into timeline; compare potential ones with each other more easily; knowing what is being played or uploaded on timeline

Question 6b: Please comment on why you feel this to be the case (confidence).

- P1: because I wasn't familiar with the interface. Overall process was very systematic. I just need to use it a few more times to be confident with the system i.e. some more scenarios in the experiment.
- P2: felt quite confident because the method was quite clear. I am not sure how confident I would be if this was for real, though, regarding quality of sound, transitions, etc.
- P3: It was quick and intuitive to use.
- P4: The cue-sheet system was great, but as soon as I started working with sound, i.e. listening and interacting based on what I planned, I felt unable to achieve what I wanted due to limitations in the database / sound generation system.

- P5: Took a while to get going and learn what I needed to know, but once I had assimilated I could play quite quickly. Would like to be able to audition the sounds in the choice screen. The pop up telling me how long they were and quick description compensated for this somewhat. Could add the category e.g. Foley to this pop up as well. Or represent this overlay by colour? Arranging the sounds by musical, non-musical etc was useful. Finding the sounds when you have a larger database will be important. Maybe display the sound you have chosen for each event on the timeline? I had to write it down as I couldn't remember the number/description of each sound after I had chosen it.
- P6: I felt like it was an easy method to use, but the tool is currently cumbersome, which did inhibit the experience somewhat.
- P7 (-)
- P8: Didn't feel hugely confident, but probably would after a bit of practise with the system. P11: with the help of this system, the sound track will be more acceptable and easy recognized since it is created by myself.

Question 7: Please comment on your response (like to use this method again)

- P1: Yes if the interface is somehow simpler. I knew that this experiment was purely focused on the method, not interface design. But when there are a lot of information (e.g. buttons, texts, frames) on the screen and not easy to find it can distract the method flow. I suppose when the interface become "transparent" i could be benefit more from this well designed structure.
- P2: The method builds upon principles I know from other design programmes, such as Adobe Flash. So it is quite easy for me to relate to it in general.
- P3 As before, it was quick and intuitive to use
- P4 (-)
- P5: I would like to see the next iteration and have another play
- P6: If I needed to create an audio interface I would do it this way again.
- P7: Very useable and enjoyable too
- P11: I think this system could save a lot of effort when making a sound track for many type of events.

Question 9b: Please comment on the usability of the tools as they are to date.

- P1: The text was too small.

- P2: Cue sheet: As I mentioned before, I got a bit confused with the different categories and with what needed to go where. Also as mentioned before, I am used to work visually so I would probably rather go for a mind map than a table, especially when it comes to interdependencies between events. Database: What is a bit irritating about the database is that the initial selection for all sound files is UA1 and that once something is selected this does not switch back other files to neutral - it is consequently very difficult to find the one you selected and I very often had forgotten by then, which one it had been. As mentioned before, it would be great to be able to playback the sound files in the database interface. Timeline: I am somehow missing markers on the timeline because the time given at the top does not have actually any meaning - how (the sequence and timing) the sound files are played depends on the occurrence of events not necessarily the time in seconds.
- P3: The cue sheet was a simple few clicks - fast and performed as expected. The timeline was a great visual cue that you could move around audio events in the space
- P4: The timeline needs some polishing in terms of user interaction
- P5: I had some problems with not being able to resize bars and there are too many separate screens to manage just now, maybe why I missed the cue sheet and went for pen and paper!
- P6: Currently the cue sheet has limited text-editing functions (you need to click directly in the box to type, even when tabbed to the box, and it doesn't accept commas etc), and the timeline seems fragile/temperamental, but in full working order this would be a great tool. The sound should match the event length, either cropped or repeated to fit.
- P7: Cue sheet is helpful and makes using the timeline much easier
- P9: Timeline should have some improvements in the control of the length, positioning and playback of the samples
- P10 (-)
- P11: I think both of the cue sheet and the timeline panel are necessary procedures in this system.

## Appendix E

# Study Four Tasks, Questions and Open-Ended Feedback

### E.1 Tasks

The following text documents the tasks that participants carried out. The text is a direct quote of the text that participants read. Any text that is preceded and ended by a star (\*text\*) describes further visuals that the participants could see and the text inside the **information** help files (this is additionally italicised).

#### **Presented to the Participant**

##### **Introduction**

This is a system to help you get an insight into creating auditory displays and sonifying data. The system borrows ideas from soundtrack composition. The method has a few steps starting with the idea of working with a scenario, analysing it, mapping sound and finally auditioning sounds and re-iterating design ideas. The following 7 steps will guide you through the method using the tools to support this. The tools are there to show the potential of the system, so bear with the prototype at this stage.

##### **Method Steps and Tools**

###### **1. Scenario**

This is an example of a scenario that we have gathered data from. We want to represent the data in sound in order that we can make decisions about how best to manage activities in a retail outlet. One could use almost any example and any data set. We want to study

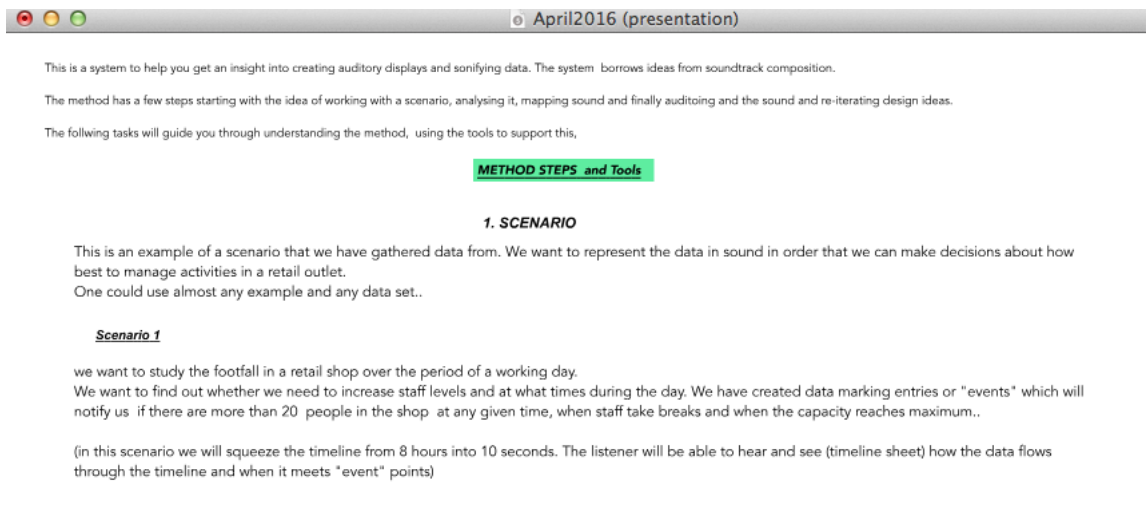


Figure E.1: Introduction and scenario.

#### **First Task**

For this example, Please can you enter footfall numbers in the 10 boxes provided. Choose numbers between 1 and 100.

Figure E.2: Data and events. Task one.

the footfall in a retail shop over the period of a working day. We want to find out whether we need to increase staff levels and at what times during the day. We have created data marking entries or “events” which will notify us if there are more than 10 people in the shop at any given time, when staff take breaks and when the capacity reaches maximum. In this scenario we will squeeze the timeline from 10 hours into 10 seconds. The listener will be able to hear and see (on the timeline) how the data flows through the timeline and when it meets “event” points.

\* Figure E.1 illustrates the screen participants viewed. \*

## **2. Data and Events**

### **First Task**

For this example, Please can you enter footfall numbers in the 10 boxes provided. click the icon below. Choose numbers between 1 and 100. Click on the image below.

\* Figure E.2 illustrates the window that participants could interact with once they had clicked the icon. Participants could enter numbers into each number box using the mouse to scroll or text entry.\*

### **Second Task**

We will now look at the other bits of information that will enable us to create this auditory display. Look at the Cue Sheet by clicking on the image below. The events are here as examples. How the events within the scenario are interpreted and what association or cause they have is subjective and can be changed. No right or wrong!. a)user action event (E1 in cue sheet) as the manager who is busy working on other tasks we want to be notified when checkout staff have their coffee and lunch breaks. We have entered three times or “event” when these happen. Please view E1-E3 text field on the cue sheet.

b) system action event (E4 in cue sheet) as the shop manager we allow for 1 checkout person per 10 customers in the shop. If the footfall rises above this point we need to be notified so that we can move a member of staff from stock taking to the tills. Please note that we have completed E4 text field on the cue sheet as a “threshold” event . In this scenario we have just one System Action Event to illustrate the principle. In reality there would be several to mark every time 10 people entered the store.

c) data point event (E5 in cue sheet) As the manager of the shop we need to be notified for health and safety reasons if the footfall rises above the full capacity of 70 people at any one time. We have completed the E5 text field on the cue sheet with this “data point event”

By completing the cue sheet we have now identified all the events to sonify this experience in order to answer the questions we may have, and represent all the information we have about our scenario. We will hold the cue sheet on file as our future reference point. And we will use it to fill in “the timeline” the interactive element that will display the audio.....

\* Figure E.3 illustrates the window that participants could interact with once they had clicked the icon. \*

### **3. Laying it out**

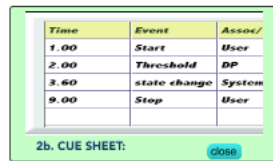
#### **Third Task**

Please view the time line (this will be open already). Now press “load example 1”, below. We have uploaded the data from the cue sheet and data set from task 1. You can see the following in the timeline:

Row one has 3 user action events. The first one is green, the second is pink and the third is blue. These represent the three state change events we marked out earlier in the cue sheet. The 2nd row has one system action event, highlighted in green. This represents the threshold event we marked out in the cue sheet representing the footfall rising above 10. The 3rd row has one data point event, highlighted green which represents the threshold event e identified to represent when the footfall reaches 70. The 4th row marks out the dataset. The 5th row contains one continuous event which is there to represent a “background” event.

## Second Task

We will now look at the other bits of information that will enable us to create this auditory display. Look at the Cue Sheet.



Time	Event	Assoc./
1.00	Start	User
2.00	Threshold	DP
3.60	state change	System
9.00	Stop	User

2b. CUE SHEET: close

The events are here as examples. How the events within the scenario are interpreted is subjective.

a. user action event (E1 in cue sheet)

as the manager who is busy working on other tasks we want to be notified when checkout staff have their coffee and lunch breaks. We have entered three times or "events" when these happen. Please view E1-E3 text field on the cue sheet.

b . system action event (E4 in cue sheet)

as the shop manager we allow for 1 checkout person per 10 cutomers in the shop. If the footfall rises above this point we need to be notified so that we can move a member of staff from stock taking to the the tills. Please note that we have completed E4 text field on the cue sheet as a "threshold" event .

c. data point event (E5 in cue sheet)

As the manager of the shop we need to be notified for health and safety reasons if the footfall rises above 70 people at any one time. We have completed the E5 text field on the cue sheet with this "data point event"

By completing the cue sheet we have now identified all the events to sonify this experience in order to anser the questions we have about our scenario. We will hold the cue sheet on file as our future reference point. And we will use it to fill in "the time-line " the interactive element that will display the audio

Figure E.3: Data and events. Task two.

We will come to this later but simply it allows us the option to create a background sound, considering the context for our scenario.

Try moving any of the user, system or data point events by placing the mouse cursor over them, left-clicking and dragging.

Try pressing the play icon (green triangle). Notice the vertical moving line and how it loops through the scenario every ten seconds.

Press stop.

Now we will decide on our audio to sonify this data and events

\* Figure E.4 illustrates the timeline that participants could interact with once they had clicked the icon.\*

## 4. Create and Map Audio

**Task 4-6 Overview** Designing the audio: We are now going to design an audio display to represent this data, so that a floor manager could listen to it and get a rapid overview of



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### 3. LAYING IT OUT

#### **Third Task**

Please view the time line.

Now press "load example 1", below. We have uploaded the data from the cue sheet and data set from task 1. You can see the following in the time-line:

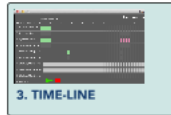
Row one has 3 user action events. The first one is green, the second is pink and the third is blue. These represent the three state change events we marked out earlier in the cue sheet.

The 2nd row has one system action event, highlighted in green. This represents the threshold event we marked out in the cue sheet representing the footfall rising.

The 3rd row has one data point event, highlighted green which represents the threshold event identified to represent when the footfall reaches 70.

The 4th row marks out the dataset.

The 5th row contains one continuous event which is there to represent a "background" event. We will come to this later but simply it allows us the option to create a background sound, considering the context for our scenario.



load example 1

Try moving any of the user, system or data point events by placing the mouse cursor over them, left-clicking and dragging.

Try pressing the play icon (green triangle). Notice the vertical moving line and how it loops through the scenario every ten seconds. Press stop.

Now we will decide on our audio to sonify this data and events .

---

Figure E.4: Layout it out. Task three.

activity in the retail outlet. In the following tasks we are going to do the following:

- a) Decide how to map the actual values of the footfall of customers
- b) Decide an appropriate background sound to provide an appropriate under pinning mood for the display
- c) Map the specific events described above, such as staff members having a coffee, being moved from stock taking to the till or footfall exceeding the threshold.
- d) Apply a final mix by adjusting sound levels where required to fine tune the display to make it as appropriate to the task and as effective a representation of what is going on as possible.

#### **Fourth Task: create melody, instrumentation and rhythm**

The data set from task 1 gets "played" in the timeline audio. As the designer of the audio you have to decide how to map our data. Currently there are options to match it different instruments and to change the speed of playback. Please click the image below, then select the option (from 1-8) in the new window that you feel would most represent the data used in our shop scenario.

\* Figure E.5 illustrates the window that participants could interact with.\*

\* Within this they had option to choose between options 1-8 and hear the data mapped to different pitched sounds. There were also a play and stop button and 4 speed settings

#### Task 4- 6 Overview

designing the audio

We are now going to design an audio display to represent this data, so that a floor manager could listen to it and get a rapid overview of activity in the retail outlet. In the following tasks we are going to do the following:

- Decide how to map the actual values of the footfall of customers
- Decide an appropriate background sound to provide an appropriate underpinning mood for the display
- Map the specific events described above, such as staff members having a coffee, being moved from stock taking to the till or footfall exceeding the threshold.
- Apply final effects where required to fine tune the display to make it as appropriate to the task and as effective a representation of what is going on as possible.

#### Fourth Task: create melody, instrumentation and Rhythm

The data set gets "played" in the timeline audio. As the designer of the audio you have to decide how to map our data. Please click the box that this would most represent the data used in our shop scenario, scenario1.



Figure E.5: Pitch and speed. Task four.

they could choose from that played the rate of playback. Additionally, there was an **information icon** that they could “click if they wanted to know more about the logic and mappings”. Within this was written the following:

*Why Map numbers to sound? in sonification this is called parameter-mapping sonification, whereby the data parameters map directly to parameters in the audio. This serves as a direct translation between the two. Here we have mapped the numbers 1-100 to frequency. We also have assumed the data can be treated like characters. In a soundtrack there is convention to establish characters through audio and often assign them motifs or instruments. Soundtracks have melodies so the challenge here is to see if our data "characters" can form the melody as a result of being mapped to audio. Scales for mood and characterisation Instrumentation for characterisation and character association.*

*Exactly how is it mapped here? the data (numbers) are mapped to pitch (notes). If the number is between 1-10 it is low and if it is between 90-100 it is high. The numbers between are scaled accordingly. The inputs you can select from the 1-8 option are mapped to instrumentation. These become incrementally more tuneful as the number you can select increases. For example 1 is mapped to percussion and 10 to piano.\**

**Fifth Task: create background audio** As the designer of the audio you have to decide whether the background audio (our scenario in the real world) is set in a natural or industrial environment, or on a scale between the two. Please click the image below and then select the option (from 1-5) in the new window that you think most represents this world and could enhance your scene.

#### **Fifth Task: create background audio**

As the designer of the audio you have to decide whether the background audio (our scenario in the real world) is set in a natural or industrial environment, or on a scale between the two. please click the box that you think most represents this world.



Figure E.6: Background. Task five.

\* Figure E.6 illustrates the window that participants could interact with. Within this they had option to choose between options 1-4: ‘Wind, Sea, Calm, Electric and String’. \*

\* There was the option to “click the **information icon** if they wanted to know more about the logic and mappings”. Within this was written the following: *what does the background do? in a soundtrack background sounds such as ambience can be used to establish a location and place. The sound can also give perception to the sense of size of the location as well as enhance mood and feel on quite a subconscious level. The sound will be continuous and likely slip in and out of consciousness but will always enhance your scene in some form.\**

*what to consider when choosing your background: where the display is heard, who the users are, how the background could change the feel of your data and events*

*THE OPTIONS: there are 5 options for you here that move from natural to man-made sounds..*

*Suggestion: try putting this to quite a low level when it comes to the final mix.\**

**Sixth Task: add affects and music** View the timeline. We have added the events that that are in the cue sheet. (They are colour coded please see above). We will now sonify these events with audio. There is a selection of audio examples.

You can play with The Effects and Music Box and the selection of sounds used, for now, to represent the events. Click on the image (4d) below. When you have done so first click on the icons to listen, then when you want to select your chosen sound, you use the drop down menu and select an event to map this sound to.

\* Figure E.7 shows the screen participants could interact with. They could press the series of icons (everyday objects or musical notes) and in doing so hear the associated sound and read the tag. There was the option to “click the **information icon** if they wanted to know more about the logic and mappings”. Within this was written the following: *What is Foley? when sounds are mapped to actions. Why use them here? In sonification research “auditory icons” refer to sounds that represent actions and every day recognisable actions. For example the “trash can” sound on you mac. The sound can represent the action*

#### **Sixth Task: add effects and music**

View the Time-line

We have added the events that are in the cue sheet. (They are colour coded please see explanation key) We have sonified these events with audio . There is a selection of other audio examples.

You can play with The Effects Box, first click on the icons to listen, then when you want to select your chosen sound, you use the drop down menu and select an event to map this sound to.

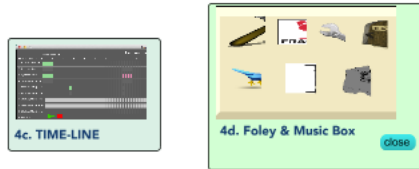


Figure E.7: SFX/Foley. Task six.

*What are motifs? memorable musical patterns that are short and often associated with characters, behaviours, narrative events. They are repeated but often, when done so, are altered in instrumentation or ‘feel’ but still recognisable. This might serve to map to actions, narrative events that perhaps cannot be associated with a real-world sound. \**

## **5. Arrange Audio**

**Seventh Task** Now we can listen to our data and events and manipulate sounds if you want to to change the audio to make the scenario sound more appropriate to you. The events are not necessarily in the correct order according to how they have been laid on the cue sheet, so you can also move these about to suit your auditory display. For example it may be suitable for this example scenario to move the data point event to a point when the dataset increases? Explore how the sounds work together. Note: the timeline could be longer, there could be more events, more data points and longer displays. But what this method and tool serves to do is support you in prototyping and exploring ideas. Try changing the numbers in the data set, the speed they are looped, or moving events about or changing the sound effects, music or background sounds to ones that you think might suit your scenario and the people involved You can change the levels of each event by playing with the “Mix” interface (figure E.8 illustrates the mix window that participants could interact with). Have fun!

**Seventh Task**

now we can listen to our data and manipulate sounds if you want to to change the audio to make the data sound more appropriate to you.

Try changing the numbers in the data set, the speed they are looped, or moving events about or changing the sound effects, music or background sounds to ones that you think might suit your scenario and the people involved

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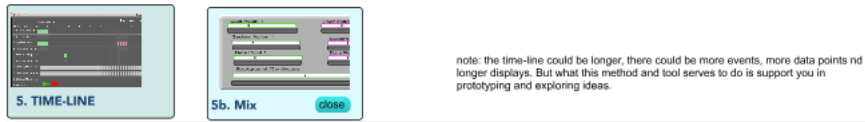


Figure E.8: Arranging audio. Task seven.

## E.2 Open-Ended Responses

**Questionnaire: Do you think the system help with your understanding, if so how?**

P1: Yes, very much. Improved my understanding. The tools illustrate the method clearly

P2: The system helped to present the events in the past nicely. I imagine I am the manager of the shop, it will be a pleasant way for me to get the footfall information as well as the number of breaks the staff took. Listening to this sonified music instead of reading a report would be nice, but if I am relying on the data to make decisions I would still prefer numbers and tables. Tutorial: In general the system helped me understand every bit of sound it played, i also gained a good understanding on how to make the effect I liked using the system

P3: Demonstrated the application of data sonification to a real world scenario

P4: Yes it helped me understand how data could be mapped into sound, and its purpose (through the example scenario)

P5: Yes, By explaining clearly what the remit was and then demonstrating, in a enjoyable way, how to create a an auditory display and then play with it. It was simple, accessible, clear and well presented

P6: Data Sonification - deals with numbers that I put/change/manipulate in input fields, options on the interface. Then these data are made into sound. Auditory Displays: are representations of auditory information above P7: Yes of course. This system gives me a very clear example of how to sonificate data and display it through audio modality. And also take the graphic representation of the information heard helps me visualise the auditory events

P8: It showed me that there were lot of components to think about. Also that I may have made terrible sonic decisions for the poor person who ends up having to my beeps and

twangs all day when trying to work! Enjoyed seeing how you'd map an event to a sound and playing around with the different gadgets. There were a few 'aha' moments :-)

P9: Yes. It made it really straightforward and instructions were very clear. I particularly enjoyed the last task -7, section 5. I have lots of ideas now!

P10: Yes! The system demonstrated how everyday action /re-actions could be communicated using audio. This could have a huge amount of value to lots of scenarios. It felt rather easy to assign a particular sound to any given action /data point. As well as notifying what is going on, real time, it could also be really useful to review and identify trends, thus it could be a very effective planning tool (as well as monitoring tool).

P11: Yes. I could see how you use data to build layers of sound and how starts and stops and frequency of sound told me things

### **Question 1: Rate the usability: please explain your response**

P1: The narrative process makes sense, but the interface needs a bit of tuning for a more fluid user experience, e.g. some of the context links between windows are not very clear - colour keys, lots of boxes are numbered where descriptions would be more helpful. The separate windows might be more helpful integrated into one.

P2: It is nice to be able to change the volume of the sounds that associated to the events. In this way, I can make important event more noticeable. In general, I feel in good control and is able to change all the aspects of the sound.

P3: I could see the system being useful for a number of real world applications.

P4: I found the system very easy to use and quite enjoyable.

P5: Well explained and accessible without having much prior knowledge

P6: The interface is now a lot easier than others that I have tried before and it has clear step-by-step instruction as well as having immediate feedback to user input

P7: Before this study, I have no idea of data sonification and audio display, no to mention creating it. This system gives me a very direct and efficient way to generate audio display. Also, the system is intuitive to use.

P8: The system was quite intuitive but having the testing spread over two screens and with a non-cooperative mouse, meant it was a bit harder to handle for someone used to single screens only

P9: The instructions were very clear and everything worked well

P10: Clear layout and instructions were provided

P11: I'm a very visual person and understandably as a prototype the presentation is quite crude but I could totally understand what to do, it was straightforward to use and I enjoyed

playing with the data once I had made the system work

**Question 3: Rate the enjoyability of the system: Please explain the reason for your response. What did you enjoy/not enjoy etc?**

P1: It's nice to create a sound track to data

P2: I like to design a personalised sound and actually listen to the sound I produced. It is enjoyable when I listen to the sound and can actually tell what the event is happening at the moment (because I designed the sound). Only wish there are less steps to follow to get what I want. Maybe you can provide more default settings when it's actually in use.

P3: I would have liked to make use of more and different sounds, maybe inputting them myself

P4: I liked listening to the 'track' I was creating through choosing and modifying the various sounds. I also like the visual representation and seeing the playback in real time

P5: I was happy that I could understand the system easily and then thoroughly enjoyed creating a display. It was fun

P6: I would find it enjoyable if there was a task for me to work on so I could try achieving it. That would be joyful for me.

P7: The system gives me a very efficient way to play with data sonification though I have little knowledge on it.

P8: Well it was rather good fun making beeps and other sounds line up events, and there being a nice brief learning curve from 'what am I doing?' to 'oh, I see!'

P9: I liked how I could make it change sounds and frequency. Having the opportunity to play around with it all at the end was a nice touch

P10: I enjoyed thinking about all the various ways that this system could support/improve every day lives

P11: I enjoyed playing once I had learned how to use the system. I didn't like the look of the system. It appeared more complicated than it was in reality and better presentation would resolve this "gosh this looks complicated and wordy - will I understand this??" feeling that I had when I initially looked at it.

**Question 4: How useful do you think this system would be for designing real auditory displays and sonifications? Please comment on your answer**

P1: It seems a straight forward way to think about constructing an AD.

P2: The outcome represents the events well, and sounds pleasant.

P3: The demo showed this

P4: I can see the potential of the system for scenarios as the one proposed as example during the user test. It's easily customisable for whatever use one has in mind.

P5: The accessibility and simplicity (as a user) of the system

P6: My specialism is not related to sound design but having tried features/options for sound manipulation of the interface i think the user will not only get their work done easily but also enjoy the ease of using the interface.

P7: This system is very direct and easy to use. It's like a concept sketch before any real displays

P8: I don't know :) Depends whether or not such a thing would be set up by the sound designer. In the example I played with I was pretending to be a supervisor setting the system to let me know when something was happening that I needed to attend to or be aware of -so I as an 'end user' might need more info about what it I was trying to achieve. Whereas if I was a sound designer using the system to create a bespoke auditory display for a client then its very useful.

P9: I would really like to use with historical data being archived online. I think this kind of audio display would be great for a variety of students needs and could make education more accessible for all. There are endless possibilities here I think

P10: Designing real auditory displays and sonifications is exactly what this system does

P11: I think the system as it is now as a prototype still makes me think that this could be worked on, adapted and used in real world scenarios. I think its a really usable tool

**Question 5: Would you use this system again? Please explain your response and what, if any, changes you would make to it if you were to use it again**

P1: I am not a AD composer

P2: It's nice to have a different way to perceive your data. I would like it more if the system makes real time response to the events. e.g. It would be nice to use the system along with a baby monitor with some sophisticated computer vision algorithms. If a baby wakes up, rolled over, or even fall off the bed the monitor can make a warning sound otherwise it makes nice music.

P3: Allow the user to adapt it to their needs

P4: I don't see myself currently in need to use the system, but i would definitely use it if i needed to monitor changes while also focusing on something else

P5: It was fun and simple . I cannot think of any changes required



P6: ... if there is an opportunity for me to work with data sonification.

P7: If I use it again, I hope it could give me some suggestions when I assign the sound samples to the events

P8: Yes, if it was freely available on the internet I would play around with it and tell people about it. Though to be honest (sadly) I don't have much call to create auditory displays

P9: I would like to find out more about how to adapt this for history teaching. Maybe if a programme could be designed to aid revision and as I really do think there is scope within the increasingly popular method of digitally archiving historical documents

P10: I could use this system in a variety of ways. It would be better still if, when the user hovers over 'user action', 'system action' and 'data point', a brief explanation appeared

P11: I can imagine that if I needed data sonifying then this is what I would turn to. I can't think of any other systems that would do this

### **Question 6: What other scenarios and applications could you imagine this being used for?**

P1: sport events, data sonification, live data performance tool.

P2: I would like if it can respond to real time events. Then it can be used in public areas such as cafeterias. The system can be related to the play list the cafe is using. When there are more customers in the shop, play some pop music or music with a quick tempo, customer might eat faster and leave quicker. When there are only few people in the cafe, play some classic music to ease the pressure of customers.

P3: analysis of any complex system e.g. scientific research

P4: For tasks or cases that need constant monitoring and need to fire alerts if changes happen, while users are occupied doing something else. Almost like a background monitor.

P5: Petrol consumption. When client payments made to bank account (might be too complex but would be really helpful) Metered water consumption. When I need coffee!

P6: I think it can be applied to use with any storyline/events that needs auditory display. Not limited to only moving image or sound based projects.

P7: Music education, aiding system for sensory-impaired people, mobile application, animal monitoring, and so on..

P8: Transport hubs like railways stations and airports, either for people (queues building up, need more staff on check in desks etc) or for the logistics of moving bags (airports) or rolling stock (sending in more carriages) or even having an alert for a problem with trains and getting rail replacement busses.

P9: Digital archives. Revision aids. Teaching aids especially for students with special edu-

cational needs

P10: To help workers ‘keep an ear’ on their work. To help supervisors monitor staff activity. To help managers review data and plan accordingly. To add auditory an notification to already exisiting IT systems (in vehicles/computers/classroom environments). Hugely beneficial to people with impairments.

P11: In vehicles for optimum performance and monitoring. For use in medical and sporting monitoring equipment. for monitoring energy use in the home/business. for use in extreme locations for monitoring yourself/the environment. to aid a person with disability/medical condition. For anyone that is multitasking any situation and needs to monitor and respond to situations while engaged in another activity

### **Question 7: Any Other Comments**

P2: Maybe integrate all the windows together one? You can use tab to switch between different controllers. That will make the application seems more user friendly.

P4: Found the system very easy to learn and enjoyable :)

P5: A very enjoyable study . Simple and fun to use. Thank you

P7: I hope it could include more samples for people to choose.

P8: I enjoyed playing with it and had no idea quite what to expect

P9: Impressive stuff!

P10: This system has endless potential!

# References

- Abrams, S., & Bellofatto, R. (2002). Qsketcher: an environment for composing music for film. In *Proceedings of the 4th conference on creativity and cognition (c and c)* (p. 157-164). ACM.
- Albers, M. (1994). The Varese System, hybrid auditory interfaces and satellite-ground control: Using auditory icons and sonification in a complex, supervisory control system. In *In proceedings of the second international conference on auditory display*.
- Alty, J. (1995). Can We Use Music in Computer- Human Communication? *People and Computers X and Proceedings of HCI '95*, 409–423.
- Alty, J., Rigas, D., & Vickers, P. (2005). Music and speech in auditory interfaces : When is one mode more appropriate than the other? In *Proceedings of the 11th international conference on display* (pp. 351–357).
- Arning, C., & Gordon, A. (2006). Sonic semiotics: the role of music in marketing communications. In *Esomar annual conference, london*.
- Back, M., & Des, D. (1996). Micro-narratives in sound design: Context, character, and caricature in waveform manipulation. *Proceedings of the International Conference on Auditory Display (ICAD)*.
- Baier, G., Hermann, T., & Stephani, U. (2007). Event-based sonification of eeg rhythms in real time. *Clinical Neurophysiology*, 118, 1377-1386.
- Barrass, S. (1996a). Earbenders: Case based from stories about listening. In *Proceedings of the first asia-pacific conference on human computer interaction apchi'96* (pp. 47–67).
- Barrass, S. (1996b). EarBenders: using stories about listening to design auditory interfaces. In *In proceedings of the first asia-pacific conference on human computer interaction apchi* (Vol. 96).

- Barrass, S. (1997). *Auditory Information Design* (Unpublished doctoral dissertation).
- Barrass, S. (2010). Probing preferences between six designs of interactive sonifications for recreational sports, health and fitness. In *Proceedings of ison* (p. 23-29).
- Barrass, S. (2012). The aesthetic turn in sonification towards a social and cultural medium. *AI & Society*(27), 177-181.
- Barrass, S. (2013). Embedding sonifications in things. In *Proceedings of the international conference on auditory display*.
- Barrass, S. (2014). Acoustic sonification of blood pressure in the form of a singing bowl. In *sonihed -conference on sonification of health and environmental data*.
- Barrass, S., & Frauenberger, C. (2009). A communal map of design in auditory display. In *Proceedings of the 15th international conference on auditory display* (pp. 1–10).
- Barrass, S., & Vickers, P. (2011). Sonification Design and Aesthetics. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 145–171). Logos Publishing House, Berlin, Germany.
- Beauchamp, R. (2005). *Designing Sound for Animation*. Focal Press.
- Beilharz, K., & Ferguson, S. (2009). An interface and framework design for interactive aesthetic sonification. In *Proceedings of the 15th international conference on auditory display*.
- Bengler, B., & Bryan-Kinns, N. (2013, June). Designing collaborative musical experiences for broad audiences. In *Proceedings of the 9th acm conference on creativity and cognition* (p. 234-242). ACM.
- Ben-Tal, O., Berger, J., Cook, B., Daniels, M., Scavone, G., & Cook, P. (2002). Sonart : The Sonification Application Research Toolbox. In *Proceedings of the 2002 international conference on auditory display, kyoto, japan, july 2-5, 2002* (pp. 2–4).
- Benyon, D. (2010). *Designing interactive systems: A comprehensive guide to hci and interaction design* (2nd ed.). Pearson Education Ltd.
- Benyon, D., & Macaulay, C. (2002). Scenarios and the hci-se design problem. *Interacting with Computers*, 14, 397-405.

- Bishop, M. J., & Sonnenschein, D. (2012). Designing with sound to enhance learning : Four recommendations from the film industry. *The Journal of Applied Interactional Design*, 2(1), 5-15.
- Black, C. (2010, October). An Overview of Spatialised Broadcasting Experiments with a Focus on Radio Art Practices. *Organised Sound*, 15(03), 198–208. doi: 10.1017/S1355771810000257
- Blandford, A. (2013). *The encyclopedia of human-computer interaction*. Available online at [http://www.interaction-design.org/encyclopedia/semi-structured\\_qualitative\\_studies.html](http://www.interaction-design.org/encyclopedia/semi-structured_qualitative_studies.html)(checked20/07/16) : *InteractionDesignFoundation*.
- Blattner, M. (2000, July). A Design for Auditory Display. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 44(1), 219–222. doi: 10.1177/154193120004400159
- Blattner, M., Sumikawa, D., & Greenburg, R. (1989, March). Earcons and icons: Their structure and common design principles. *Human-Computer Interaction*, 4(1), 11–44. doi: 10.1207/s15327051hci0401\_1
- Bødker, S., & Nylandsted Klokmoose, C. (2016). Dynamics, multiplicity and conceptual blends in hci. In *Proceedings of the 2016 chi conference on human factors in computing systems* (p. 2538-2548). ACM.
- Bordwell, D., & Thompson, K. (1985). Film sound: Theory and practice. In (p. 181-199). Columbia University Press.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Using Qualitative Research in Psychology*, 3(2), 77-101.
- Brazil, E. (2009). A review of methods and frameworks for sonic interaction design: Exploring existing approaches. In (p. 41-67). Brazil, E. (2010). A review of methods and frameworks for sonic interaction design: Exploring existing approaches. In Auditory Display (pp. 41-67). Springer Berlin Heidelberg.
- Brazil, E., & Fernström, M. (2009). Subjective Experience Methods for Early Conceptual Design of Auditory Displays. In *Proceedings of the 15th international conference on auditory display (icad)* (pp. 1–8).
- Brazil, E., & Fernström, M. (2011). Auditory Icons. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 325–338). Logos Pub-

- lishing House, Berlin, Germany.
- Brewster, S. (1991). *Providing A Model For The Use Of Sound In User Interfaces*. University of York, Department of Computer Science.
- Brewster, S. (1998, December). The design of sonically-enhanced widgets. *Interacting with Computers*, 11(2), 211–235. doi: 10.1016/S0953-5438(98)00028-9
- Brewster, S. (1999, January). Non-visual interfaces for wearable computers. *COLLOQUIUM DIGEST-IEE*, 6-6.
- Brewster, S. (2002). Overcoming the lack of screen space on mobile computers. *Personal and Ubiquitous Computing*, 6(3), 188-205.
- Brewster, S., & Wright, P. (1995). Parallel earcons: Reducing the length of audio messages. *International journal of human-computer studies*, 43(22), 153-175.
- Brewster, S., Wright, P., & Edwards, A. (1994a). The design and evaluation of an auditory-enhanced scrollbar. *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*(April), 173–179.
- Brewster, S., Wright, P., & Edwards, A. (1994b). A detailed investigation into the effectiveness of earcons. *SANTA FE INSTITUTE STUDIES IN THE SCIENCES OF COMPLEXITY-PROCEEDINGS VOLUME-*, 18, 471-471.
- Brooke, J. (1996). Sus: A quick and dirty usability scale. *Usability evaluation in industry*, 189-194.
- Buxton, B., Gaver, W., & Bly, S. (1994). Auditory Icons. In *Auditory interfaces: The use of non-speech audio at the interface* (chap. Chapter 6).
- Buxton, W., Gaver, W., & Bly, S. (1989). Chapter 5 : EVERYDAY LISTENING. In (pp. 1–22).
- Callum, S. H. C., H Andrew, Sorensen, A., & Brown, A. (2008). Metascore : User interface design for generative film scoring. In *Proceedings of sound : Space - the australasian computer music conference (acma)* (p. 25-30).
- Carroll, J. (2000). *Making use: scenario-based design of human-computer interactions*. Cambridge, Massachusetts. London, England: The MIT Press.
- Chion, M. (1994). *Audio Vision. Sound on Screen* (C. Gorbman, Ed.). Columbia University Press.
- Cohen, A. (1998). The Functions of Music in Multimedia: A cognitive Approach. In *Music, mind, and science*, (p. 53-69.).

- Cohen, J. (1992). Monitoring background activities. In G. Kramer (Ed.), *Auditory display* (p. 499-531). New York: Addison Wesley Longman.
- Coleman, G., Macaulay, C., & Newell, A. F. (2008). Sonic mapping: towards engaging the user in the design of sound for computerized artifacts. In *Proceedings of the 5th nordic conference on human-computer interaction: building bridges* (p. 83-92). ACM.
- Collins, K. (2009, February). An introduction to procedural music in video games. *Contemporary Music Review*, 28(1), 5-15.
- Cooley, M. (1998). Sound+ image in computer-based design: learning from sound in the arts. In *Proceedings of the fifth international conference on auditory display* (pp. 1-10).
- Davis, R. (2010). *Complete guide to film scoring: The art and business of writing music for movies and tv* (2nd ed.). Berklee Press.
- DeCampo, A. (2007). A data sonification design space map. In *Proceedings of the 2nd international workshop on interactive sonification* (pp. 1-4).
- DeCampo, A., Frauenberger, C., & Holdrich, R. (2004). Designing a generalized sonification environment. In *Proceedings of the International Conference on Auditory Display*.
- Diaper, D., & Stanton, N. (Eds.). (2004). *The handbook of task analysis for human-computer-interaction*. Lawrence Erlbaum Associates.
- Diniz, N., Deweppe, A., Demey, M., & Leman, M. (2010). A Framework for music-based interactive sonification. In *16th international conference on auditory display*.
- Dix, A. (1998, September). Finding out. event discovery using status – event analysis. In *Proceedings of formal aspects of human computer interaction fahci98*.
- Dix, A., & Abowd, G. (1996). Modelling status and event behaviour of interactive systems. *Software Engineering Journal*, 11(6), 334.
- Dix, A., & Brewster, S. (1994). Causing trouble with buttons. In D. England (Ed.), *Ancillary proceedings of hci'94*.
- Dix, A., Leite, J., & Friday, A. (2007). Xsed-xml-based description of status-event components and system. In *Engineering interactive systems (eis2007)*.
- Dombois, F., Brodewolf, O., Friedli, O., Rennert, I., & Koenig, T. (2008, June). Soni-

- fyer: a concept, a software, a platform. In *Proceedings of the 14th International Conference on Auditory Display* (p. 14-17).
- Dombois, F., & Eckel, G. (2011). Audification. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 301–324). Logos Publishing House, Berlin, Germany.
- Droumeva, M. (2005). Understanding immersive audio: a historical and socio-cultural exploration of auditory displays. In *Proceedings of the 11th meeting of the international conference on auditory display* (pp. 162–168).
- Droumeva, M., & McGregor, I. (2012). Everyday listening to auditory displays: lessons from acoustic ecology. In *Proceedings of the 18th international conference on auditory display* (pp. 52–59).
- Edwards, A. (1989). Soundtrack: An auditory interface for blind users. *Human-Computer Interaction*, 4, 45–66.
- Fagerlön, J., & Liljedahl, M. (2009). Awesome sound design tool : A web-based utility that invites end-users into the audio design process. In *In proceedings of the 15th international conference on auditory display (icad)*.
- Fagerlön, J., & Liljedahl, M. (2010). Designing a web-based tool that informs the audio design process. In S. Ystad, M. Aramaki, R. Kronland-Martinet, & K. Jensen (Eds.), (pp. 68–79). Springer- Verlag.
- Fauconnier, G., & Turner, M. (2003a). Conceptual blending, form and meaning. *Recherches en communication*, 19(19), 57-86.
- Fauconnier, G., & Turner, M. (2003b). *The way we think: Conceptual blending and the mind's hidden complexities*. Basic Books.
- Frauenberger, C., & Stockman, T. (2009, November). Auditory display design-an investigation of a design pattern approach. *International Journal of Human-Computer Studies*, 67(11), 907-922.
- Frauenberger, C., Stockman, T., & Bourguet, M.-L. (2007). A survey on common practice in designing audio in the user interface. In *Proceedings of the 21st british hci group annual conference on people and computers: Hci... but not as we know it* (Vol. Volume 1, p. 187-194). British Computer Society.
- Gaver, W. (1989, March). The SonicFinder: An Interface That Uses Auditory Icons. *Human-Computer Interaction*, 4(1), 67–94. doi: 10.1207/s15327051hci0401\_3



- Gaver, W. (2012, May). What should we expect from research through design? In *Proceedings of the sigchi conference on human factors in computing systems* (p. 937-946). ACM.
- Gaver, W., & Smith, R. (1990). Auditory icons in large-scale collaborative environments. *Interact*, 90(1990), 735-740.
- Gaver, W., Smith, R., & O'Shea, T. (1991). Effective sounds in complex systems: The ARKola simulation. *Conference on Human factors in computing systems. ACM Press/Addison-Wesley*, 1991, 85-90.
- Gerson, N., & Page, W. (2001, August). What storytelling can do for information visualization. *Communications of the ACM*, 44(8), 31-37.
- Gibson, J. (1986). *The ecological approach to visual perception*. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.
- Go, K., & Carroll, J. (2004). The handbook of task-analysis for human-computer-interaction. In D. Diaper & N. Stanton (Eds.), (p. 117-135). Lawrence Erlbaum Associates, Inc.
- Gomery, D. (1985). The coming of sound: Technological change in the american film industry. In E. Weiss & J. Belton (Eds.), *Film sound: Theory and practice*. (p. 25-36). Columbia University Press.
- Gorbman, C. (1987). *Unheard melodies: narrative film music*. BFI Publishing.
- Gourdazi, V., & Vogt, K. (2015). Observations on an interdisciplinary design process using a sonification framework. In *International conference on auditory display* (p. 81-85).
- Grice, S. (2006). *The uses of audio in interface design: in particular the use of music* (Unpublished doctoral dissertation). Dundee University.
- Grond, F., & Berger, J. (2011). Parameter Mapping Sonification. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 363-397). Logos Publishing House, Berlin, Germany.
- Hankinson, J. C. K., & Edwards, A. D. N. (1999, September). Designing earcons with musical grammars. *ACM SIGCAPH Computers and the Physically Handicapped*(65), 16-20. doi: 10.1145/569306.569307
- Hankinson, John, C., & Edwards, A. D. N. (2000). Musical Phrase-Structured Audio Communication. In *Proceedings of the 6th international conference on*

*auditory display, atlanta, ga, usa, 2000.*

- Hansen, K., & Bresin, R. (2012). Sonification of distance between stations in train journeys. In *Smc sweden 2012 sound and music ...* (Vol. 52, pp. 13–14).
- Hermann, T. (2008). Taxonomy and Definitions for Sonification and Auditory Display. In *Proceedings of the 14th international conference on auditory display* (pp. 1–8).
- Hermann, T. (2011). Model-based sonification. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 399–427). Logos Publishing House, Berlin, Germany.
- Hermann, T., Hunt, A., & Neuhoff, J. G. (2011a). Chapter 1 Introduction. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 1–6). Berlin: Logos Publishing House, Berlin, Germany.
- Hermann, T., Hunt, A., & Neuhoff, J. G. (2011b). *The Sonification Handbook* (T. Hermann, A. Hunt, & J. G. Neuhoff, Eds.). Berlin: Logos Publishing House, Berlin, Germany.
- Hildebrandt, T., & Rinderle-Ma, S. (2013). Toward a sonification concept for business process monitoring. In *International conference on auditory display* (p. 323–330).
- Holman, T. (2010). *Sound for Film and Television* (Third ed.). Elsevier/Focal Press.
- Höner, O., Pauletto, S., Röber, N., Hermann, T., & Effenberg, A. O. (2011). Aiding Movement with Sonification in “ Exercise , Play and Sport ”. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 538–546). Logos Publishing House, Berlin, Germany.
- Hug, D. (2009). Using a Systematic Design process to investigate Narrative Sound Design Strategies for Interactive Commodities. In *Proceedings of the 15th international conference on auditory display, copenhagen, denmark may 18 - 22, 2009* (pp. 1–8).
- Hug, D., & Misdariis, N. (2011). Towards a conceptual framework to integrate designerly and scientific sound design methods. In *Proceedings of the 6th audio mostly conference: A conference on interaction with sound* (p. 22–30). ACM.
- Jeon, M. (2010). Two or three things you need to know about aui design or designers.

- In *Proceedings of icad 10-sixteenth meeting of the international conference on auditory display*.
- Joseph, A., & Lodha, S. (2002). Musart: Musical audio transfer function real-time toolkit. In *Proc. of icad 02-tenth meeting of the international conference on auditory display (icad)*.
- Kalinak, K. (1991). Music to my ears: A structural approach to teaching the soundtrack. *Indiana Theory Review*, 29-45.
- Kalinak, K. (2010). *Film music: A very short introduction*. Oxford University Press, Inc.
- Kramer, G. (Ed.). (1994). *Auditory display. sonification, audification and auditory interfaces*. Addison Wesley Publishing Company.
- Kramer, G., & Walker, B. N. (2005). Sound science: Marking ten international conferences on auditory display. *ACM Transactions on Applied Perception (TAP)*, 2(4), 383-388.
- Leplâtre, G., & Brewster, S. (1998). Perspectives on the design of musical auditory interfaces. *International Journal of Computing ...*, 227-239.
- Leplâtre, G., & McGregor, I. (2004). How to Tackle Auditory Interface Aesthetics? Discussion and Case Study. In *Proceedings of the international conference on auditory display*.
- Liljedahl, M. (2009). Tapping into effective emotional reactions via a user driven audio design tool. In *in proceedings of audio mostly - a conference on interaction with sound*.
- Liljedahl, M., & Fagerlönn, J. (2010). Methods for sound design: a review and implications for research and practice. In *Proceedings of the 5th audio mostly conference: A conference on interaction with sound* (p. 2). ACM.
- Lipscomb, S., & Tolchinsky, D. (2005). The role of music communication in cinema. *Musical communication*, 383-404.
- Lodha, S., Beahan, J., Heppe, T., Joseph, A., & Zane-Ulman, B. (1997). Muse: A musical data sonification toolkit.
- Lodha, S., Wilson, C., & Sheehan, R. (1996). Listen: Sounding uncertainty visualization. In *Proceedings of the 7th annual ieee visualization*.
- Ma, K.-L., Liao, I., Frazier, J., Hauser, H., & Kostis, H.-N. (2012, Jan-Feb). Scien-

- tific storytelling using visualization. *IEEE Computer Graphics and Applications*, 32(1), 12-19.
- Malandrino, D., Mea, D., Negro, A., Palmeiri, G., & Scarano, V. (2003). NeMoS: Network Monitoring with Sound. In *Proceedings of the 2003 international conference on auditory display, boston, ma, usa, july 6-9, 2003* (pp. 1-5).
- Mauney, B., & Walker, B. (2004). Creating Functional and Livable Soundscapes for Peripheral Monitoring of Dynamic Data. *Proceedings of ICAD*, 7-11.
- McGookin, D., & Brewster, S. (2011). Earcons. In T. Hermann, A. Hunt, & J. G. Neuhoﬀ (Eds.), *The sonification handbook* (pp. 339-361). Logos Publishing House, Berlin, Germany.
- McGookin, D., & Brewster, S. (2011). PULSE: an auditory display to provide a social vibe. *IWS '11*.
- McGregor, I., Crerar, A., Benyon, D., & Leplâtre, G. (2006). Mapping Workplace Soundscapes: Reifying Office Auditory Environments. *World Forum of Acoustic Ecology (WFAE)*, 1-16.
- McGregor, I., Larsson, P., & Turner, P. (2011). Evaluating a vehicle auditory display: comparing a designer's expectations with listeners' experiences. In *Proceedings of the 29th annual european conference on cognitive ergonomics*. ACM.
- McGregor, I., Leplâtre, G., Turner, P., & Flint, T. (2010). Soundscape Mapping : A Tool for Evaluating Sounds and Auditory Environments. *The 16th International Conference on Auditory Display (ICAD-2010) June*.
- McLachlan, R., McGee-Lennon, M., & Brewster, S. (2012). The sound of musicons: Investigating the design of musically derived audio cues. In *International conference on auditory display (icad)* (pp. 148-155).
- Monache, S. D., Polotti, P., & Rocchesso, D. (2010). A toolkit for explorations in sonic interaction design. *Proceedings of the 5th Audio Mostly Conference on A Conference on Interaction with Sound - AM '10*, 1-7. doi: 10.1145/1859799.1859800
- Monk, A., & Gilbert, N. (Eds.). (1995). *Perspectives on hci: Diverse approaches*. Academic Press.
- Mynatt. (1994). Designing with auditory icons. *Proceedings of ICAD'94*.

- Nees, M. (2012). Correlations of scatterplots: A comparison of auditory and visual modes of learning. In *Proceedings of the International Conference on Auditory Display* (p. 195-198).
- Neuhoff, J. G. (2004). *Ecological psychoacoustics*. Elsevier Academic Press.
- Parseihian, G., & Katz, B. (2012). Morphocons: a new sonification concept based on morphological earcons. *J Audio Eng Soc (accepted 2012-01-19)*, 409-418.
- Pauletto, S., Cabridge, H., & Rudnicki, R. (2014). Sonihed conference on sonification of health and environmental data. In R. R. Sandra Pauletto Howard Cabridge (Ed.), . York University.
- Pauletto, S., & Hunt, A. (2004). A toolkit for interactive sonification. In *Proceedings of icad 04-tenth meeting of the international conference on auditory display*.
- Pauletto, S., & Hunt, A. (2009, November). Interactive sonification of complex data. *International Journal of Human-Computer Studies*, 67(11), 923-933. doi: 10.1016/j.ijhcs.2009.05.006
- Peres, C., Best, V., Brock, D., Shinn-Cunningham, B., Frauenberger, C., Hermann, T., ... Stockman, T. (2008). Audio Interfaces. In Kortum, P (Ed.), *Hci beyond the gui. design for haptic, speech, olfactory and other nontraditional interfaces* (chap. 5 Auditory Interfaces). Morgan Kaufman Publishers.
- Peters, N., & McAdams, S. (2007). Proceedings of the 13th international conference on auditory display..
- Pirhonen, A., Murphy, E., McAllister, G., & Yu, W. (2006). Non-speech sounds as elements of a use scenario : A semiotic perspective. In *Proceedings of the 12th international conference on auditory display (icad)* (p. 134-140).
- Rigas, D., Alty, J., & Long, F. (1997). Can music support interfaces to complex databases? In *Proceedings of the 23rd euromicro conference* (p. 78-84).
- Rubin, B. (1998). Audible information design in the new york city subway system: A case study. In *Proceedings of the international conference on auditory display* (pp. 1-6).
- Sanderson, P., Liu, D., & Jenkins, S. (2009). Auditory displays in anesthesiology. *Current Opinion in Anaesthesiology*, 22(6), 788-795.
- Schaeffer, P. (1967). *Traité des objets musicaux* (Vol. rev. edition). Seuil, Paris.
- Schafer, M. (1977). *Our sonic environment and the soundscape: the tuning of the*

*world*. Destiny Books.

- Schaffert, N., & Gehret, R. (2013). Testing different versions of functional sonification as acoustic feedback for rowing. In *Proceedings of the International Conference on Auditory Display* (p. 331-335).
- Schaffert, N., & Mattes, K. (2012). Acoustic feedback training in adaptive rowing. In *Proceedings of the International Conference on Auditory Display*.
- Schaik, P.-V., & Ling, J. (2003). Using on-line surveys to measure three key constructs of the quality of human-computer interaction in web sites: psychometric properties and implications. *International Journal of Human-Computer Studies*, 59, 545-567.
- Segal, E., & Heer, J. (2010, November). Narrative visualization: Telling stories with data. *Visualization and Computer Graphics, IEEE Transactions on*, 16(6), 1139-1148.
- Somers, E. (2000). Abstract sound objects to expand the vocabulary of sound design for visual and theatrical media. In *Proceedings of the international conference on auditory display*.
- Sonnenschein, D. (2001). *Sound design: The expressive power of music, voice and sound effects in cinema*. Michael Wiese Productions.
- Sonnenwald, D. H., Haberman, G., Keese, W. M., Myers, J. S., & Bank, R. (1990). Infosound: An Audio Aid. In *Twenty-Third Hawaii International Conference on System Sciences, IEEE Computer Society Press*, 11, 541-546.
- Sova, D., & Nielsen, J. (2003, 21/06/2016). *234 tips and tricks for recruiting users as participants in usability studies* (Tech. Rep.). <http://www.nngroup.com/reports/tips/recruiting/>.
- Tunnermann, R., Hammerschmidt, T., & Hermann, T. (2013). Blended sonification for casual information. In *International conference on auditory display* (p. 119-126).
- Turner, M. (2003). *Cognitive dimensions of social science: The way we think about politics, economics, law, and society*. Oxford University Press; New Ed edition (27 Mar. 2003).
- Valjamae, A., Steffert, S., Holland, S., Marimon, X., Benitez, R., Mealla, S., & Jordà, S. (2013). A review of real-time eeg sonification research. In *Proceedings of*

- the International Conference on Auditory Display* (p. 85-91).
- Ventura, D. (2010). *Film music in focus* (2nd ed.). Rhinegold Publishing.
- Vickers, P. (2004). Sonification and Visualisation of Narrative: Getting Computing Students to Think Aurally and Visually Rather Than Audio-Visually. In *Proceedings of icad 04-tenth meeting of the international conference on auditory display*.
- Vickers, P. (2011). Sonification for Process Monitoring. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 455–491). Logos Publishing House, Berlin, Germany.
- Vickers, P., & Alty, J. (2002). Musical program auralisation: a structured approach to motif design. *Interacting with Computers*, 14(5), 457-485.
- Vickers, P., & Hogg, B. (2006). Sonification Abstraite / Sonification Concrete : An ‘ Æsthetic Perspectice Space ’ for classifying Auditory Displays in the Ars Musica Domain. *Proceedings of the 12th International Conference on Auditory Display 2006*, 210–216.
- Vogt, K., Pirr, D., Kobenz, I., & Robert, H. (2009). Physiosonic - movement sonification as auditory feedback. In *Proceedings of the International Conference on Auditory Display*.
- Walker, B., & Cothran, J. (2003). Sonification sandbox: A graphical toolkit for auditory graphs. In *Proceedings of the 11th International Conference on Auditory Display*.
- Walker, B., & Kramer, G. (2004). Ecological psychoacoustics and auditory displays: Hearing, grouping, and meaning making. *Ecological psychoacoustics*, 1–32.
- Walker, B., Nance, A., & Lindsay, J. (2006). Spearcons: Speech-based Earcons improve Navigation Performance in Auditory. *Proceedings of ICAD*, 63–68.
- Walker, B., & Nees, M. (2011). Theory of Sonification. In T. Hermann, A. Hunt, & J. G. Neuhoff (Eds.), *The sonification handbook* (pp. 9–39). Logos Publishing House, Berlin, Germany.
- Weiss, E., & Belton, J. (Eds.). (1985). *Film sound: Theory and practice*. Columbia University Press.
- Whittall, A. (2001). *Leitmotif*. Grove’s Dictionaries, New York (checked 8/07/16).
- Williamson, j., Murray-Smith, R., & Hughes, S. (2007). Shoogle: Multimodal

- excitatory interaction on mobile devices. In *Proceedings of the sigchi conference on human factors in computing systems* (p. 121-124). ACM.
- Wilson, C., & Lodha, S. (1996). Listen: A data sonification toolkit. In *Proceedings of icad 96- 3rd meeting of the international conference on auditory display*.
- Wolf, K., & Fiebrink, R. (2015). End-user development of sonifications using soundscapes. In *The 21st international conference on auditory display* (p. 281-288).
- Yewdall, D. (2003). Foley: The art of footsteps, porps and cloth movement. In *The practical art of motion picture sound* (chap. 16). Focal Press.
- Zhao, H., Plaisant, C., Shneiderman, B., & Duraiswami, R. (2004). Sonification of geo-referenced data for auditory information seeking: Design principle and pilot study. In *Proceedings of the International Conference on Auditory Display*.
- Zimmerman, J., Forilizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in hci. In *Proceedings of the sigchi conference on human factors in computing systems* (p. 493-502). ACM.
- Zimmerman, J., Stolterman, E., & Forilizzi, J. (2010). An analysis and critique of research through design: towards a formalization of a research approach. In *Proceedings of the 8th acm conference on designing interactive systems* (p. 310-319). ACM.